TOWARDS THE EXTENSION OF THE KNOWLEDGEBASE TO FURTHER THE UNDERSTANDING AND MODELLING OF DRIVER BEHAVIOUR

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

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ABSTRACT

The problem of how the mind relates to the brain stands as one of the greatest challenges today. The materialistic worldview and pragmatic approach to social problems are both being transformed by discoveries of how human experience and culture arise in cerebral activity. Even so, this effort, spearheaded by neuroscience, has seen the important and contentious issue of driver behaviour somehow been left behind.

From an extensive literature study, it can be concluded that gross disregard of the neural underpinnings of such behaviour tied to a behaviouristic approach is endemic to the field. Numerous qualitative psychological models (each associated with debates about their validity) and Artificial Intelligence models, which effectively only imitate robots 'impaired' to display some humanlike characteristics, were come across. Although neural networks are derived from current knowledge of computation within the brain and deployed in industry, human driver behaviour modelling is not benefiting from this revolution in humanlike information processing.

To date, very little has been done to determine what makes road users speed, drive while drunk, overtake, or yield at crossroads. As the central nervous system is the human measuring device in and of the world and thus key affector of human behaviour, it is of utmost importance to invest resources in 'inoculating' the field of driver behaviour modelling onto a robust basis provided by neuroscience. Being a human driver incorporates a broad complement of interrelated brain systems to perform driving tasks (psychological functions) at hand, such as lane keeping, speed choice, risk perception, and obstacle avoidance. The proper level of analysis of such a psychological function is the level at which that function is represented in the brain. Providing a theoretical model of human behaviour, based on biological facts of the brain as a whole, is surely a challenge for decades to come, but the field of driver behaviour should be part of such an effort.

Collaboration is needed among investigators from the fields of neuroscience, psychology, mathematics, computer science, and engineering to further driver behaviour modelling. It is uncommon that professionals from these fields have a thorough understanding of the other fields involved, but the author, not pretending to be an expert, argues that such a union of fields will be of significant value not only to transportation, but all behavioural sciences. The wealth of to-date knowledge amassed in neuroscience lies ready to be tapped by researchers interested in explaining

human driver behaviour. To this end, the use of modern brain-imaging techniques will be invaluable in pinning down the neural correlates of particular driving subtasks, bearing in mind the extent of structural impacts on the brain of each individual, brought about by a lifetime of interaction with the environment.

Thus, based on the findings of this literature study, the author proposes that supplementary work be conducted by a multi-disciplinary team to roll-out an experiment to study the nature of environmental stimuli as instigators of aggression and road rage, by drawing on knowledge about brain imaging and (amygdala) activation.

ABSTRAK

Die vraagstuk hoe die verstand [denke] met die brein in verband staan, is een van die grootste uitdagings tans. Die materialistiese wêreldbeskouing sowel as die pragmatiese benadering van maatskaplike probleme word verander deur ontdekkings aangaande die wyse waarop menslike ervaring en kultuur hul in serebrale aktiwiteit voordoen. Desondanks is in hierdie poging, met die neurowetenskap aan die spits, die belangrike en omstrede kwessie van bestuurdersgedrag om een of ander rede agterweë gelaat.

Uit ’n uitgebreide literatuurstudie kan afgelei word dat grootskaalse verontagsaming van die neurale basis van sodanige gedrag gekoppel aan ’n behavioristiese benadering endemies is aan die gebied. Talle kwalitatiewe sielkundige modelle en kunsmatige intelligensiemodelle is teëgekom, elk gepaard met debatte oor die geldigheid daarvan. Hoewel neurale netwerkmodelle gebaseer word op huidige kennis van verwerking binne die brein en ontplooi word in die industrie, trek menslike bestuurdersgedragmodellering nie voordeel uit hierdie revolusie in neurale inligtingsverwerking nie.

Tot op hede is baie min gedoen om vas te stel waarom padgebruikers jaag, dronkbestuur, verbysteek of by kruispaaie toegee. Aangesien die sentrale senuweestelsel die menslike meettoestel in en van die wêreld is en dus die sleutelbeïnvloeder van menslike gedrag is, is dit van die uiterste belang om middele te investeer in die fundering van die gebied van bestuurdersgedragmodellering op ’n stewige basis daargestel deur die neurowetenskappe. Om ’n menslike bestuurder te wees behels ’n omvattende komplement van verbandhoudende breinstelsels om bestuurstake (sielkundige funksies) te verrig, soos spoedkeuse, risikowaarneming en die vermyding van obstruksies. Die gepaste ontledingsvlak van so ’n sielkundige funksie is die vlak waarop daardie funksie in die brein verteenwoordig word. Die daarstelling van ’n teoretiese model van menslike gedrag, gebaseer op biologiese feite van die brein in die geheel, is gewis nog vir komende dekades ’n uitdaging, maar die gebied van bestuurdersgedrag moet deel uitmaak van so ’n poging.

Samewerking is nodig tussen navorsers uit die neurowetenskappe, sielkunde, wiskunde, rekenaarwetenskap en ingenieurswese om bestuurdersgedragmodellering te bevorder. Dit is ongewoon dat vakkundiges uit hierdie velde ’n deeglike begrip het van die ander gebiede wat betrokke is, maar die outeur, sonder om voor te gee dat hy ’n deskundige is, betoog dat so ’n

samesnoering van vakgebiede van betekenisvolle waarde sal wees, nie net vir die vervoerwese nie, maar ook vir al die gedragwetenskappe. Die omvang van die jongste kennis wat in die neurowetenskappe vergaar is, lê gereed om deur navorsers benut te word wat belang stel in die verklaring van menslike bestuurdersgedrag. Met dié doel sal die gebruik van moderne breinskanderingstegnieke van onskatbare waarde wees om die neurale korrelate van bepaalde bestuursubtake vas te pen, gedagtig aan die omvang van strukturele impakte op die brein van elke indiwidu teweeggebring deur ’n leeftyd van interaksie met die omgewing.

Daarom, gebaseer op die bevindinge van hierdie literatuurstudie, stel die outeur voor dat addisionele werk gedoen word deur ‘n multi-dissiplinêre span ten einde ‘n eksperiment uit te voer, waarin die aard van stimuli uit die omgewing, wat lei tot padwoede, bestudeer kan word, met inagneming van die beskikbare kennis oor breinskandering en (amygdala) -aktiveringpatrone.

"O LORD our Lord, how excellent is *thy name in all the earth! who has set thy glory above the heavens. When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; What is man, that thou art mindful of him? and the son of man, that thou visitest him? For thou hast made him a little lower than the angels, and hast crowned him with glory and honour. Thou madest him to have dominion over the works of thy hands. O LORD our Lord, how excellent* is *thy name in all the earth!"*

"The days of our years are *threescore years and ten; and if by reason of strength* they be *fourscore years, yet* is *their strength labour and sorrow; for it is soon cut off, and we fly away. So teach* us *to number our days, that we may apply* our *hearts unto **wisdom**."*

"Search me, O God, and know my heart: try me, and know my thoughts: And see if there be any *wicked way in me, and lead me in the way everlasting."*

"Give instruction *to a wise* man, *and he will be yet wiser: teach a just* man, *and he will increase in learning. The fear of the LORD* is *the **beginning of wisdom**: and the knowledge of the [Holy One]* is *understanding."*

Psalm 8
Psalm 90
Psalm 139
Proverbs 9

to Colleen: mine and yours forever

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INTRODUCTION – THE ISSUE OF DRIVER BEHAVIOUR MODELLING

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1.1.1 Traffic management and networks

Future transportation systems will integrate many sophisticated technologies. These technologies will include congestion prediction, dynamic routing, incident detection algorithms, automated emergency response generation, and real-time adaptive control algorithms to control entrance ramp access, lane use signals, mainline flow, congestion advisories, and emergency information. Systems of this complexity may lead to a large number of diverse and complex interactions between the different components of the system. Computer simulations which couple the traffic control logic with a lane level traffic model which accurately represents the movements of vehicles through the network can provide an understanding of these interactions and motivate possible improvements to the design of the system.

Traffic management systems are dynamic systems which measure traffic conditions and respond to these measurements by activating lane use signs, variable speed limit signs, variable message signs, and ramp and mainline meters, and by giving motorists information via highway advisory radio and other in-vehicle devices. These control actions alter the paths and the behaviour of individual vehicles en route to their destinations. In turn, the response of the motorists to current control strategies impacts future control actions that are implemented by the traffic management system. This feedback or interaction between the control system and the traffic flow system is a key issue of an evaluation. This requires that the simulation incorporate models for driver response.

Only microscopic simulation models provide the required level of detail and only a model which provides the capability of modelling the dynamic interaction between the traffic management system and the traffic flow on the network is appropriate for evaluation of these systems. Many of the older generation of microscopic models have several drawbacks which limit their use in this evaluation effort. In general, these models were developed for specific networks (freeways or urban networks) but not for integrated networks. Furthermore, even though more recent versions do simulate integrated networks, they do not model in sufficient detail driver behaviour, or driver response to traffic control and information and hence cannot be used for evaluation of certain lane specific control strategies (for example lane use signal control and mainline control). Moreover, many of these models generally do not allow en route path diversions but instead determine vehicle paths exogenously. As a result, reaction of motorists to congestion information and routing recommendations cannot be easily incorporated.

1.1.2 Human factors and safety

Transportation lies between a social system and a physical system – it goes beyond physics to a human scale. On the physical side are the striking variety and number of vehicles and road systems, each contributing its own peculiarities, as well as the weather and other environmental factors. The social, behavioural side encompasses not only the individual preferences and second-by-second reactions of drivers but also actions taken by the rest of society. To understand the forces acting on traffic flow, transportation planners have to analyse the many possible outcomes from this complex network of decisions (Howard, 1997).

As mentioned above, traffic systems are undergoing enormous change with the advent of Intelligent Transport Systems (ITS). Although productivity and quality of mobility are emerging interests, safety remains the predominant preoccupation of ITS human factors. It should be evident that while intelligent technologies may have the potential to improve traffic safety, they also have the potential to adversely affect it. Ultimately, the effect on safety depends on the specific technologies that are invoked and the manner in which they are incorporated within the vehicle as well as within the larger road transportation system. Current automotive developments can be characterised as technology-centred solutions rather than user-centred solutions. Greater effort must be directed at understanding and accommodating the human element in the road transportation system in order that future transportation objectives can be achieved. There is a need to expand the scope of traditional human factors to include macro-level effects as well as to place greater emphasis on understanding human interactions with other elements of the system (Noy, 1997).

Intelligent driver interfaces (IDI) will increase the complexity of the driving task. On the one hand, new technologies expand the solution space beyond conventional boundaries. On the other hand, the solution selected must be optimised with respect to usability, suitability, safety and user acceptance. The increasing complexity of the interface requires that one understands and develops computational models for complex human-system interactions. Current efforts to generate human factors design guidelines, principles and data, intense as they are in the USA and Europe, are important in addressing immediate needs. However, they are inadequate in the medium- to long-term because they will not yield a coherent body of knowledge of human response and adaptive behaviour in traffic. Computational models based on sound theory would be far more valuable and usable by designers (Noy, 1997).

Current IDI trends towards greater automation and greater use of information technologies demand much greater emphasis on understanding driver cognitive factors than is currently evident. The proliferation of auxiliary instrumentation (for example, navigation displays) is especially problematic due to the greater potential for interference between operational-level cognitive requirements and higher-order, strategic-level cognitive requirements (Kantowitz, 1997). A black box model of the human driver is no longer adequate to address the emerging needs of system designers (Thierry et al., 1996). In addition, according to Rasmussen (1990), scientific work in modern high-tech societies calls for a reconsideration of the notion of human error – research should be focused on a general understanding of human behaviour and social interaction in cognitive terms in complex, dynamic environments, not on fragments of behaviour called 'error'. This approach has similarities to the 'risk homeostasis' theories of traffic safety, with the reservation that the controlling mechanisms are adaptation in a wider sense than control governed by criteria related to risk. Designers need models of the human information-processing system that will predict driver decision-making, situational awareness and strategies for negotiating in traffic. Such models, supported by much greater computing power, will revolutionise traffic analysis.

1.2 Classical Role-Players in Driver Behaviour Modelling

1.2.1 The engineer and the psychologist

Car following is a seductive phenomenon for engineers and physicists. Surely, if drivers are limited to a single lane, there is a vehicle in front of them and the physical properties of each are known, then some form of descriptive equation should capture the behaviour observed. Having presented the case for one pair, surely one can generalise to multiple pairs. Such models should then aid understanding of one predominant form of traffic accident – the rear-end collision. If such a model were successful, one would then have a basis for expansion into the less straight-forward types of manoeuvre like over-taking or turning across traffic. Soon, it would be possible to model all traffic flow phenomena and significant benefits could be reaped for all of traffic safety. Although this is a worthwhile and laudable goal, the only problem is reality (Hancock, 1999).

Real world effects have an impact on the model process at several levels. The first concerns the goal of driving and the goal of car-following models. It is safe to assert, that driving is, with few exceptions, a satisficing task (Hancock and Scallen, 1999). That is, people drive well enough to accomplish their task, but by and large they do not seek continual improvement in driving skill towards some nominal 'optimal' level. In any given situation, they do not seek to optimise their performance, although some circumstances such as racecar driving represent exceptions. The problem with a number of existing models is that they frame the question of behaviour around the idea of optimal performance (Hancock, 1999). Therefore, some models introduce factors such as 'noise' (the use of Monte Carlo techniques for stimulus- and decision selection) to help explain performance variation and sub-optimal achievement but they are founded on a flawed assumption. This often leads to a confused and confusing search for the equivalence between a physical characterisation such as closing velocity and a psychological phenomenon such as the onset of avoidance action.

While it is true that the domain of psychophysics has, for over a century, sought relations between physical intensities and psychological response, it is fair now to question this way of thinking (Hancock, 1999). People have always considered physics as reality and the psychological response as a deviation from that reality. However, independent and dependent variables are actually being mixed up, a mistake that is only now being exposed (Flach, 1999). Thus, deriving equations from physical descriptions of motion and subsequently trying to fit these to data derived from behavioural responses, both literally and figuratively, puts the cart before the horse. It is a historical result of the fact that most early modellers were trained in physics and grounded in engineering. As a result, the conclusion that such models have proved largely disappointing is not surprising although it should be noted that this is certainly no necessary reason to dismiss modelling as a useful strategy.

The reality that the pluralistic motivations of different drivers and the dominance of satisficing behaviour in driving mean that such models are unlikely to render the 'grail' of a simple formula. Differing contextual factors add layers of complexity to modelling as such factors are introduced (Ceder and May, 1976). These efforts can rapidly devolve to curve-fitting exercises in which additional degrees of freedom are added to formulations, as more contextual elements are included. What such models eventually represent, in driving terms, only their advocates can explain. Generally, there is no spark of intelligence and no learning; there is only data-driven information processing – once the parameters for a particular run of the model have been determined the programme will run strictly on the basis of fixed algorithms and further external inputs. If the outcome of a programme run will be at all surprising, it is simply because of the complexity of the computation. Some models do not even incorporate real priority interrupts. If a routine which happens to execute does not contain an instruction which tells it to check for crossing pedestrians, it will run over any number of them without even noticing (Michon, 1985).

1.2.2 What of psychological models?

Eventually, car-following models were developed which sought to include psychological variables (Groeger and Brady, 1999). Fundamentally, these models rely upon a perceptual signal to trigger avoidance behaviour. However, much of the research supporting such threshold notions have occurred in static, non-reactive, laboratory conditions, not out on the road, demanding actual decisions and responses. Thus, most so-called 'psychological' models are hybrids, using a single perceptual parameter as a start signal to 'run' a classic mathematical description. It is also debatable whether fuzzy-set models, found helpful in crossing the divide between the psychological and the physical perspective, are an answer or an escape (Hancock, 1999). In the end, some engineers ask the psychologist how notions such as motivation and attitude can be incorporated into dynamic models. It is important to understand that putatively more obvious human capacities such as vision are equally as difficult as driver attitude to fit into equations and that the apparent simplicity which chronological measures impart is just that, apparent rather than real.

A more important question remains. On what common ground will the physicist and the psychologist meet? Clearly much remains to be achieved if those of a mathematical persuasion are to change their fundamental perspective to a psychological focus while many in psychology learn to use the austere scalpel of numbers in their descriptions of behaviour (Hancock, 1999). Such a union will be of great value in transportation.

1.3 Objectives, Contributory Value, and Layout of the Reported Research

The intention of the author is not to propose a model of driver behaviour, but rather to put forward an approach in order to extend the knowledgebase on which future driver behaviour experiments and models can be built. In short, the objectives in reporting the author's research in this dissertation are to:

a) Give an in-depth account of the state-of-the-art of driver behaviour modelling to understand better the effect of behaviourism on the current stalemate and lack of new ideas in driver behaviour modelling since the 1980s.
b) Motivate, through a literature study, the power of rooting observed driver behaviour on neuroscientific knowledge, to understand better how such behaviour arises from the neural underpinnings of human brain functioning.
c) Propose ways and means of combining the knowledge from neuroscience, psychology, computer science, and engineering to lay the platform from which to study and model driver behaviour holistically in future.

Traffic engineering, as a science, needs to draw on knowledge and insights from other (usually more basic) sciences to provide the tools needed for work in the field, for example, physics and mathematics provide the basis for geometric design of roads, and statistics is an important cornerstone for conducting safety audits of a road network. Traffic engineering differs from the pure sciences in that it is more concerned with the application of scientific knowledge. It is true, when seeking solutions to real-world problems, that questions of economy and other considerations prescribe a need to employ appropriate simplifying assumptions. In order to be useful, such simplifications must render a problem amenable to efficient solution while retaining the essential aspects of the postulated situation. These assumptions are based on the current state-of-the-art and are themselves subject to change as scientific knowledge (in all sciences) is enhanced through research and additional experience. One should always be attentive to the fundamental assumptions that are involved in a particular situation and the extent to which these assumptions can affect the results (Papacostas and Prevedouros, 1993). *One such set of assumptions that is in need of being revisited and extended relates to the human dimension of models in traffic engineering, specifically the basis from which driver behaviour is understood and modelled. This perspective is supported by the findings from an extensive literature research outlined in this dissertation.*

Before attempting to argue for any changes to the current knowledgebase of driver behaviour modelling, it is essential to determine the state-of-the-art of the field. Research on drivers and the driving task covers a broad range of topics and approaches within psychology, the more basic science furnishing traffic engineers with models of human behaviour. The driving task, as complex everyday task, provides a focus for a wide range of theories and methodologies, being emphasised by the breath and the depth of contributions made. In contrast to other fields of psychology, human factors research in the area of driver behaviour has not been overhauled to the same extent through the 'cognitive revolution', which dethroned the behaviourists, and restored the inner states of mind as appropriate topics. A related problem in driver behaviour modelling revolves around the fact that rules which describe externally observable behaviour and rules which determine the functional relations which generate such behaviour tend to be confused or combined indiscriminately. On the other hand, psychological (motivational) models, such as the Theory of Risk Homeostasis and Fuller's risk avoidance model, have been criticised for being qualitative in nature, applicable only to single-instance situations, and lacking specificity regarding their internal mechanisms, which precludes validation. These issues, together with comments on the applicability of Artificial Intelligence models, such as rule-based systems, are discussed in Chapter 2, thereby sketching the state-of-the-art of the field of driver behaviour in short.

To complement the first part of this study (Chapter 2) and to render a clear and concise line of reasoning in the main part of this dissertation, uncluttered by excessive detail, a broad literature review of the extent of knowledge in the field of driver behaviour is presented later on in Appendix A. This review covers many topics over a wide front in traffic engineering and psychology and summarises knowledge, opinions, psychological measurements, and models presented in the literature on this important and complex phenomenon by other researchers. These topics relate to:

a) Culture of driving (such as traffic law enforcement, risk perception, and sensation seeking)
b) Driver training
c) Driver's perception of speed
d) Lane-keeping for straight and curve driving
e) Drivers' visual search
f) Dimensions of aberrant driver behaviour
g) Driver behaviour modelling
h) Drivers' emotions.

Considering the evidence, there is a lack of worthwhile ideas in driver behaviour modelling. A central shortcoming in most endeavours to enhance the understanding of driver behaviour seems to be rooted in the inability to base such behaviour as arising from the neural underpinnings of human brain functioning. Like in the past, failing to do so in future will repeatedly lead to numerous incompatible and qualitative models unfit for implementation in computer simulations, or else yield robot-like models, each tied to a debate about its validity. This point of view is elaborated upon in Chapter 3. The impasse in driver behaviour modelling is not due to a lack of knowledge on brain functioning and development. An ever-growing body of anatomical, physiological, and developmental facts, supported by neurally-inspired quantitative models of the brain as a key affector of an individual's behaviour, is available in the family of neurosciences. This wealth of knowledge amassed in neuroscience lies ready to be tapped by researchers interested in explaining human driver behaviour.

It is uncommon for professionals in traffic engineering (or physics), psychology, and mathematics to have a thorough understanding of neuroscience. Again, to limit the level of detail in Chapter 3, the purpose of the literature included in Appendix B is to provide *such* readers with an easy way to become to some extent acquainted with the current state of selected theory and findings in neuroscience, and a means for the interested reader to pursue particular topics in greater depth. The reported literature study is by no means exhaustive in terms of the diversity *or* level of detail of topics. As it is important to realise that research on driver behaviour really necessitates studying the central nervous system as a whole, work on unifying the modularity of brain activity, such as the approach by Grossberg (2000), produces valuable insights. Other topics relating to neuroanatomy and neurophysiology, discussed in Appendix B, include neuron activity, brain development and plasticity, perception, memory systems and learning mechanisms, motor control, and brain-imaging techniques. In addition, findings from studies relating to the neural underpinnings of social cognition and emotions are reviewed. These latter issues, together with attention and consciousness, are inseparably part of a comprehensive driver model.

Sufficient quantitative information exists about the structure of certain brain areas, and the flow of information to and from them, to build neural network models which have structural as well as neuronal plausibility. These and other connectionist models, derived from current knowledge of computation within the brain and designed to mimic human behaviour, as summarised in Chapter 3, are discussed in more detail in Appendix C. These theoretical models allow researchers to obtain a clearer view of how parts of a system contribute to the performance of the brain as a whole.

As a *direct outcome of the thoroughness of the literature study*, summarised in the first part of this dissertation, the author is in a position to propose an experimental set-up in Chapter 4, which can be put to work in the quest of finding the environmental stimuli serving as aggression (and road rage) instigators. As is the case with the in-depth proposal for the extension of the knowledgebase of driver behaviour modelling, *this* hypothesis of the utility of brain imaging and (amygdala) activation in solving the pressing question mentioned, is also new to the field of traffic engineering. However, one cannot argue away the multi-disciplinary nature, substantial financial layout, and specialised knowledge needed from inter alia neuroscience, computer science, and psychology to eventually roll out such an experiment.

In Chapter 5 suggestions are outlined based on the finding that driver behaviour modelling be 'inoculated' onto a robust foundation provided by neuroscience. Studying driver behaviour based on inputs from psychology, as it has been the case thus far, but incorporating know-how from neuroscience in future, presents a useful application of knowledge from the two mentioned fields to enhance driver behaviour modelling. This translates into a direct contribution to traffic engineering and impacts indirectly on psychology and neuroscience as improved understanding of driver behaviour renders better understanding of human behaviour in general.

CHAPTER 2

STATE-OF-THE-ART OF DRIVER BEHAVIOUR MODELLING

2.1 Contributions of Psychology in Studying the Behaviour of Drivers

2.1.1 Overview

Research on drivers and the driving task covers a remarkably broad range of topics and approaches within psychology. The driving task, as complex everyday task, provides a focus for a wide range of theories and methodologies and allows these to be tested and elaborated in a highly relevant applied setting. While the research has often been carried out to address practical concerns, the fact that a single everyday task has elicited this involvement across the discipline of psychology stands in marked contrast to the fractionation and demarcation which is evident in much current psychology. This point is easily made by looking at the various groupings psychologists have organised themselves into within the many psychological societies and organisations. However, as mentioned below, research on driving is also important to psychology, being emphasised by the breath and the depth of contributions made (Groeger and Rothengatter, 1998).

2.1.2 Driver's perception and cognition

Through studying driving, research within the memory tradition, such as that by Chapman and Groeger (1998) on memory for risk related and emotionally arousing driving events or that by Maycock, Lester and Lockwood (1996), which strongly indicates a 'forgetting factor' in retrospectively reported traffic accidents, offers important insights into what is now described as episodic memory (Groeger, 1997). These, together with the studies by Gugerty (1997) and Perrig and Kintsch (1985) on way-finding and thus spatial memory, and the massive proceduralisation of elements of the driving task, and thus involvement of procedural memory make clear the scope for significant contributions to both mainstream memory research and driver behaviour.

Attention, as a crucial aspect of cognition, has also been widely studied within the driving literature, through research on attention switching and workload (Verwey and Veltman, 1996), and the dependence on some general attentional or intellectual resources (Duncan, 1993). In describing aspects of attention, almost every author in mainstream psychology uses driving as a paradigm case of automaticity, although closer analysis of even the least complex aspects of the driving task, such as gear changing, does not conform to many of the assumptions made (Groeger and Rothengatter, 1998).

2.1.3 Developmental approaches

Within developmental or life span approaches to psychology, transportation is also represented. Some of this work relates to evaluating the effectiveness of various traffic safety education programmes. Furthermore, a number of studies have linked early behavioural difficulties and personality characteristics with the adoption of unsafe driving practices in later adolescence (Caspi et al., 1997; Moffitt et al., 1996). At the other end of the age spectrum the considerable difficulties encountered by elderly drivers using the traffic system include those suffering from dementia and other age associated disabilities and have been the focus of increasing attention (Poser, 1993).

2.1.4 Social psychology of driving

A considerable amount of research in social psychology has also focused on driving and drivers. This work includes, for example, the link between attitudes and behaviour, extensions of Ajzen's (1991) theory of planned behaviour and the role of driver affect and emotion in violations of road traffic conventions (Lawton et al., 1997). A range of other work, explores the various social cognitive biases which operate on drivers assessments of themselves, other drivers, the situations they find themselves in, and the risks they confront. These biases include, for example, attribution bias, false consensus bias, unrealistic optimism and the illusion of control (Greening and Chandler, 1997).

2.1.5 Driver state

Issues relating to stress, fatigue and arousal have been themes in psychological studies of driving and transport operation for a considerable amount of time. Studies in this area tend to be motivated by practical rather than theoretical concerns, but the research nevertheless makes a considerable contribution to the human factors literature, from near visionary in-car information handling systems envisaged in the GIDS project (Michon, 1993) back to the very early selection studies for drivers of commercial vehicles.

2.1.6 Individual differences

Much research has considered the extent to which personality and life style factors contribute to accident causation. The focus on personality factors has been enduring, and reflects the historical developments in more mainstream work on the topic. Recent research by Arthur and Graziano (1996), applies the now dominant five-factor model of personality to accident involvement, and finds that those lacking in Conscientiousness are at greater risk. The work of Mercer and Wayne (1995) demonstrates convincing relationships between actual personality characteristics, violations of traffic and other laws and recidivism, and thus opens up die possibility of early identification of those more likely to be involved in accidents.

2.1.7 Applications

From the early days of driver testing, traffic psychology has not just provided a theoretical basis for understanding road user behaviour but also has contributed to the development of accident countermeasures. While this development is still largely focused on measures aimed to improve road users' skills, cognitions and attitudes, impact on vehicle and road design is on the increase, which is in part a result of the introduction of road transport informatics now commonly known as Intelligent Transport Systems. Driver error, intentional or unintentional, has been identified as a major contributory factor in the accident process, and novice road users – be they pedestrians, cyclists or drivers – appear to be disproportionally at risk. Education and training have therefore been the focus of attention.

2.1.8 Education

Early studies demonstrated the relevance of the development in capabilities such as speed and distance perception (Vinjé, 1981) for specifying educational objectives, for example, young children's road crossing skills. Teaching programmes which make use of principles borrowed from behaviour modification (such as prompting, feedback and incentives) proved very effective in installing safe road crossing behaviour and were used as basis for developing programmes which relied on parental training (Limbourg and Gerber, 1981). Such approaches also could be applied through mass media messages (Rothengatter, 1984) and do lead to demonstrable reduction in child accidents when implemented by television channels (Preusser and Blomberg, 1987). However, implementation in the educational system appears much more problematic.

2.1.9 Driver training

While driver training should provide the basis for safe and efficient traffic participation, there are many studies indicating that it is not (Brown et al, 1987) which is due to many factors, many of these of a practical nature which determine that psychological principles of which is known that these affect the effectiveness of training are not taken into account. Systematic feedback and error correction procedures, for example, are not systematically applied. It has been argued that driver training should be structured in accord with cognitive psychological concepts such that drivers learn appropriate production rules, but this has as yet not been applied to driver training practice (Michon et al., 1990).

2.1.10 Public information campaigns

Despite their obvious popularity among practitioners, there is very little evidence that public information campaigns are effective. It has been argued that such campaigns are mostly ineffective because they address drivers' level of perceived risk rather than drivers' level of acceptable (target) risk (Wilde, 1982, 1994). Following this line of reasoning, public information campaigns should alter drivers' subjective utilities of desired and undesired behaviour. Experiments using incentives to reward desired behaviour have demonstrated that this is indeed an effective approach, in particular in relation to seat belt usage (Geller, 1990). It is certain, however, that the potential safety benefits of such approaches have not as yet been explored in full.

2.1.11 Traffic law enforcement

The alternative to providing incentives for desired behaviour is providing disincentives or punishment for undesired, risky behaviour. The latter is the basic premise of traffic law enforcement, which has been studied extensively, albeit mostly in evaluation studies that did not analyse psychological principles for the effects found. Results from studies emphasise the importance of (subjective) probability of detection and the need to optimise this through combining enforcement strategies with public information campaigns. The reviews also clearly demonstrate that systematic and consistent application of principles derived from general behaviour-modification literature can result in significant changes in driver behaviour, most notably in speed choice and drinking driving. Much less is known about enforcement of less obvious but equally risky behaviour such 'give way' violations, aggressive driving, and antisocial driving behaviour. A major issue is also the attitude-behaviour relation, and in particular the question whether attitude change precedes, or is the result of, behaviour change. Application of automated enforcement techniques, which allows in principle a perfect objective detection rate as in speed and red-light cameras, has raised the issue of societal acceptance of, and individual reactance to, such enforcement techniques.

2.1.12 Driver improvement and rehabilitation

While detecting drivers who deviate from normative, desired behaviour may become increasingly effective, it remains the question what measures should be taken once the offending driver is detected. There is every indication that relatively small fines are hardly a deterrent, in particular for professional drivers who have substantial economic motives for violating traffic law. With respect to rehabilitating those with problem behaviours, the work reported by Utzelmann and Jacobshagen (1997) on the rehabilitation of German drivers with alcohol problems, is an important large-scale validation of the outcome of psychotherapeutic interventions.

2.1.13 Road and vehicle design

The understanding of how drivers perceive their road environment and how they process the information obtained from the environment is a key to the design of the environment. The fact that most accidents are due to driver error emphasises rather than refutes the argument that road design that is adapted to drivers' capabilities and limitations enhances safety. This approach has been termed 'self-explaining roads', 'designing for safety', or 'sustained safety design' and many studies have been carried out indicating how this can be achieved (Van Elslande and Alberton, 1997). Providing engineers with design principles which take account of drivers' capabilities, and individual as well as momentary differences in these capabilities, may be one of the most challenging tasks for traffic psychology.

2.1.14 Final remarks

This brief overview of the issues, theoretical approaches and methodologies which are current in the psychological literature on driving reveals both the richness and breath of the involvement of psychology in driving research. It may seem as if no single approach or theoretical stance is ever likely to be sufficient to account for behaviour in traffic, due to the complexity of the human behaviour been set as the goal of understanding (Groeger and Rothengatter, 1998).

2.2 Driver Models to Date – Avoiding Explanatory Pitfalls

2.2.1 Overview

Models describing observed driver behaviour, and which can be implemented in a traffic simulation procedure, can refer to either of two levels of explanation, (i) the rational or intentional level that is usually taken to represent the aggregate behaviour of the driver population, or (ii) the functional level which deals with intra-individual information processing. Frequently the two levels are confounded, which is likely to introduce serious theoretical problems – vicious circles and pernicious homunculi among them. Good driver models should move of and by themselves; they should be generative – the principal characteristic of a scientifically acceptable driver model is its propensity to generate comparatively complex behaviour from comparatively few and simple principles (Michon, 1989).

According to Michon, a possible approach to get a discussion of driver models under way would seem to categorise them according to what makes them move. A whole spectrum of possibilities exists. On the one hand there are traffic safety models which resemble ‘Dinky Toys’. They move by magic or, what amounts to the same thing, by pushing them around by hand. In traffic research there are still many such models, although eventually they will be recognised for the clever curve fitting tricks they are. At the other extreme of the spectrum will be models which move autonomously and learn from their experiences. Such models are able to cope with their environment in a reasonable way (Michon, 1989).

Reasonable (or rational) is also the term used to qualify the performance of another class of model which reacts to external inputs while ‘keeping its goals in mind’. Such models single-mindedly aim at maintaining the value of specific output variable levels without undergoing any change of their structure, as in the case of a room thermostat, for example. Models representing this kind of feedback system do not adapt their internal structure on the basis of their experiences, and it would seem farfetched to ascribe rationality to such systems and to the models which represent them (Michon, 1989). Models which are driven by concepts and adaptive rules and that are consequently able to learn belong to a class which can ultimately be said to move about in a rational fashion and keep their goals in mind. Only such models will tend to perform increasingly better and have any scientific survival value at all. Ultimately, the question remains as to whether such models are based on and advance the understanding and knowledge of the behaviour of human drivers.

2.2.2 Magic of curve-fitting

In 1949 Smeed formulated his famous formula, relating the number of fatalities on the road (D), the number of motorised vehicles (M) in a particular geographical region, and its population (P). The formula, $D = c(MP^2)^{1/3}$ did describe this relation over a period of many years and for many parts of the world (Smeed, 1949, 1968, 1972; Adams, 1985). There is, however, a serious problem with Smeed's law – no one has really succeeded in offering a plausible explanation in terms of the social psychological processes that give rise to this empirical relation. It seems an interesting coincidence that Smeed's law is formally identical to Kepler's second law, which relates the mean distance (D) of a planet from the Sun, to its period (P), $D = c(P^2)^{1/3}$. However, while Smeed's law does little else than describe the data it was derived from in the first place, Kepler's law follows directly and necessarily from Newton's law of gravitation (Michon, 1989).

Empirically, Smeed's law suddenly and drastically broke down around 1973 in countries all over the world. Thus, the formula, unlike Kepler's law evidently became what it had been in the first place – a magical toy and a clever piece of curve fitting. Despite this dramatic failure of Smeed's conjecture, there are still authors who remain faithful to it. Adams (1985), for example, claims that 'the law is still holding up remarkably well.' Unfortunately Adams is wrong, for the simple reason that in passing this judgment he has not considered data from recent years (Michon, 1989). Smeed's rule should be put to rest unless – or until – researchers succeed in explaining the rule in terms of its underlying mechanisms. Like other 'laws' – such as Kepler's second law – Smeed's law cannot and should not survive, unless its form can be deduced from the properties of the traffic system's functional architecture.

2.2.3 Risk homeostasis

The concept of the well-known Theory of Risk Homeostasis (RHT) proposed by Wilde (1982a) is deceptively simple – accident occurrence at the aggregate level is taken to be a regulatory process by means of which the level of risk in a society is kept constant. This risk is expressed in some measure of disutility or unsafety, for example, the number of fatalities. When circumstances change in such way that the objective risk of driving decreases, for instance, when the level of road maintenance improves, the behaviour of the driving population will shift towards more risky forms of behaviour. As a result the number of fatalities will remain the same, despite the improvement.

While Smeed's interpreters have failed altogether to define what processes can give rise to Smeed's law, the Theory of Risk Homeostasis has come up with just one distinct but highly overtaxed principle (note – a principle, not a process). Because at the intra-individual level homeostasis is so pervasive that it will account for almost every form of activity, it is too weak a principle to impose the right kind of constraints on behaviour. In short, ensembles of homeostats do not necessarily produce homeostatic behaviour. Non-homeostatic processes may easily generate homeostatic behaviour at the aggregate level, for example, it can be shown that risk homeostasis may be an outcome, under certain conditions, of a process of trip utility maximisation (Michon, 1989). In addition, motivational models have been criticised for lacking specificity regarding their internal mechanisms, which precludes validation (Michon, 1985; Molen and Botticher, 1988).

2.2.4 Prearranged structures

Another issue to be raised is in some sense the complement of the preceding ones. It concerns the fact that many traffic safety models which deal with individual behaviour mimic the structural elements of a task environment, rather than explain how these task elements are brought about by underlying processing mechanisms. They mimic reality in the sense that they already contain everything that is there – including everything that is there to be explained. As an example, consider a model that has been proposed by Van der Molen and Bötticher (1988, also Bötticher and Van der Molen, 1988). The aim of these authors is to develop a genuine process theory of the driver. They use descriptive terms that are consistent with the analysis of driving in terms of a three-tiered division into strategic (planning), tactical (manoeuvring), and operational (skill) aspects of the driving task (Michon, 1971).

However, the approach adopted by Van der Molen and Bötticher reflects, in the opinion of Michon (1989), a common type of conceptual error resulting from confounding the rational level and the functional (process) level. It is analogous to the (erroneous) assumption that every step in a cookbook recipe must correspond to a specific feature of the finished dish. It reflects, in other words, confusion between a grammar and the sentences that can be generated with it.

One important aspect to be highlighted is Van der Molen and Bötticher's attempt to specify processing units at each of the three levels of the driving task – planning, manoeuvring and skill. As an elementary form of task analysis this distinction has served as a convenient way of partitioning the field of driver behaviour research in manageable sub-domains. The point that Van der Molen and Bötticher seem to have missed, when they set out to implement these three levels in their process model, is that distinctions which are useful to describe what appears to be going on in driving, when adopting the intentional point of view, not at all correspond with relevant distinctions which need to be made at the functional level. Or, to combine the culinary and the linguistic metaphor of the preceding paragraph – the syntax of the kitchen does not necessarily match the semantics of the dining room (Michon, 1989).

2.2.5 Rational versus functional explanation

The preceding examples touch directly upon the important issue of confounding two levels of explanation in driver modelling, two levels that ought to be kept apart but which are frequently mixed in actual practice. One is called the intentional level, and the other the functional level.

In making this distinction with respect to driver models, the first point to observe is that aggregate behavioural models, such as Minter's (1987) learning curve explanation of Smeed's law or Wilde's risk homeostasis model do not really describe collective behaviour (Michon, 1989). Almost invariably they are treated as descriptions of central tendencies of the behaviour of an idealised (but ultimately individual) driver. Such 'prototypical' descriptions, based on the average behaviour of a whole population, a random sample, or perhaps specific segments of the population, rest heavily on the assumption that the average driver will, as a rule, behave rationally (or reasonably, intelligently, meaningfully, or whatever term may be chosen).

In contrast, genuinely individual driver models usually seem to be formulated at the functional (design) level of theoretical discourse. At this level behaviour is described in terms of (mental) functions and processes, operations performed on internally represented facts about the world. However, instead of assuming that the driver is behaving optimally (or rationally), the focus of attention in this type of model is on actual behaviour. And since actual behaviour is usually sub-optimal, the model is designed to function sub-optimally too, so as to faithfully mimic the driver's performance.

Theorists are constantly facing the risk of confounding these two levels of discourse, the rational level and the functional level. Terrible things may happen when they mix, which they frequently do (Michon, 1989). One of these catastrophes is the introduction of pernicious homunculi or, what almost amounts to the same thing, vicious circles, in one's theory. As an illustration, take Freud's psychoanalytic theory of the human person as a dynamic relation between three sub-personal components, the ego, the super-ego and the id. Everything would have been fine, had not these three components been attributed precisely the kind of properties (for example, intelligence and motivation) they are supposed to explain. The consequence will be clear – nothing is gained in the end. Ultimately Freud explained a conscious agent – the person – by postulating three (unconscious) agents (or homunculi) which were given the same sort of features the conscious agent already possessed in the first place.

Since they confound the intentional and functional levels of explanation, Minter's learning curve explanation of Smeed's law falls into the trap of vicious circularity, the Theory of Risk Homeostasis seems to be infested with pernicious homunculi, and Van der Molen and Bötticher have eliminated the generative power of their sub-personal model. In order to explain the shape of a curve describing decreasing casualty rates, an increase in experience is assumed on the basis of the same curve it is supposed to explain. In order to explain risk homeostasis as a societal phenomenon, an individual propensity towards risk homeostasis is assumed in the first place. And in order to make the behaviour of a driver appear to be governed by information processing at three levels, his/her cognitive apparatus is supplied with components that reflect these levels (Michon, 1989).

2.2.6 Stimulus-response models

It is clear that the problem how to connect behaviour at the aggregate level (as tackled by the attribution of rationality, intelligence, and so forth) with the sub-personal functional level centres around the proper separation of concepts and terms that belong to, and operate at, either level. It is, in other words, necessary to specify clearly and concisely what are elementary processes and building bricks at the functional level, and what are the complex (aggregate) behaviours that are generated by these elementary processes (Michon, 1989). This consideration partially underlies the concept of rule-based behaviour (Fuller, 1984, 1988). Fuller's model is based on the 'syntax' of instrumental conditioning. As such it deals, at the functional level, with the strength of association between stimuli and responses and with the corresponding transition probabilities between successive elements in a chain of external (or internal) actions. In Fuller's model these associative mechanisms lead eventually to actions for avoiding harmful or uncertain situations.

The model is also distinctly intentional. This is due to the fact that the behaviour which is generated by the internal workings of the rules of association and shaped by reinforcement and punishment, can be perceived as rational – it is maximising some form of subjective utility. Fuller's model does (implicitly) separate its assumptions about functional mechanisms (for example, association and reinforcement) from its assumptions about the intentional, adaptive aspects of behaviour. Approach and avoidance are rational in the context of the prevailing circumstances rather than in the context of the principles of association, and Fuller's model is consistent with this position (Michon, 1989).

According to Michon there is, however, one serious flaw in the type of model Fuller proposes. As soon as one wishes to extend it to situations which are slightly more complex than the one-shot threat-avoidance reaction to a stimulus in an otherwise static situation, one runs into significant difficulties. Technically speaking, the syntax of approach-avoidance models is that of the Markov process and Markov processes cannot account for the generativity of human behaviour.

2.2.7 Rule-based models

Based on the preceding discussion Michon (1989) favours rule-based or production-based models. However, there appears to be considerable opposition to rule-based models. The ultimate reason seems to be a belief that the rule-based model falls into precisely the trap discussed above – mixing two levels of explanation, the intentional level and the functional level. On that assumption one can understand, for example, Janssen's (1986) verdict that production-based models of the kind Michon proposed earlier (Michon, 1985) are trivial, or at best nontrivial only because the designer of the model has put in all nontrivial knowledge by hand. In a sense this is the same objection made earlier with regard to the model proposed by Van der Molen and Bötticher (1988). However, according to Michon (1989), Janssen's argument is based on a misunderstanding about the nature of the rules at the intentional or action level and their internal representation at the functional or procedural level. In other words rules which capture behaviour at the intentional level (that is, rules which can be interpreted as rational) need not correspond with rules at the functional level, but rules which determine the processes at the functional level should suffice to generate the kind of behaviour which one can call rational and that, in turn, can be described by rules at the intentional level.

How can adequate structural and functional constraints on a rule-based model be imposed, without being accused of triviality or of putting the model's intelligence in by hand? Certainly not by an a priori choice of formal constraints which are too narrow (as in the case of Fuller's threat-avoidance model). Perhaps by finding a structure which is semantically plausible; a structure which offers a context in which one can attribute a meaning to the behaviour the model is supposed to exhibit.

According to Michon (1989) such a structure is Soar, an intelligent architecture developed by Allen Newell (Laird et al., 1987). Soar is the formalisation of a theory of human problem solving, put forward by Newell and Simon (1972) and amounts to searching a problem space by applying operators to successive states of the problem. Many activities can be described in these terms. Newell (1989) even takes a more radical position by claiming that any intelligent behaviour can in principle be described as a form of problem-solving behaviour. This seems the ultimate extrapolation of the claim (Michon, 1976) that all travel behaviour (which includes driving) may be described as problem solving. This implies that Soar, because it is an exemplary problem-solving system, may be considered as a natural medium for modelling driver behaviour.

In Soar, the rules which one can write down and which seem trivial to the critics of rule-based modelling, are patterns of interconnected elements in the working memory of the system. Knowledge represented in this format is indeed trivial in the sense that it is presented to the system from the outside in a ready-made form. In short, the following will happen in Soar as a model of the cognitive activity of the human driver. Given an overriding top goal, for example, travel from point A to point B, and some knowledge about the facts of life, Soar will begin searching its working memory. It will search for a pattern of interrelated knowledge elements which has the structural characteristics of a problem space which it can search and which is, moreover, connected with the stated top goal. (One might choose to call such a pattern a scenario). If anything that answers this description is found, Soar will immediately select it. It may, of course, find nothing that meets the structural requirements of a problem space for the stated top goal. However, Soar may also find more than one pattern, since it will always test the whole content of its working memory in a parallel fashion. In both cases, when it finds no matching pattern or when it finds several such patterns, Soar will find itself in an impasse, which it will recognise as a new problem to be solved. Consequently it will specify a new goal, subordinate to the original top goal, and Soar will select as its next task to solve that particular impasse.

A feature of the internal operation of Soar is its learning mechanism, called chunking. If Soar works its way through a series of one or more impasses and finally reaches a solution which allows it to resume its primary activity – that of attaining its top level goal – it will proceed only after building a new rule which will tell it what to do when it would ever hit upon the same impasse again. It will add this rule to its rule-base and subsequently wipe its slate, that is, it will forget all the irrelevant trial and error it went through before it found the proper solution.

2.2.8 Fatal shortcomings of rule-based models

However, the author is of the opinion that Michon's preference of utilising a rule-based system (such as Soar) to model driver behaviour is flawed for a couple of reasons, apart from the findings of others (for example, Janssen, 1986). The first concerns the viewpoint that human behaviour can be viewed as a form of problem-solving behaviour. It is believed that thinking does not normally involve the pure reasoned rules of logic. This has been demonstrated in research by Johnson-Laird (1988). He found that quite often people draw logically invalid conclusions, suggesting that if the human mind is a formal logic machine, it is a poor one. People are rational, according to Johnson-Laird, but they just don't achieve their rationality by following formal laws of logic. However, Frank (1988) argues that decision-making is often not rational at all in that many actions, purposely taken with full knowledge of their consequences, are irrational. If people did not perform them, they would be better off and they know it.

Furthermore, at the functional (design) level of Michon's proposed rule-based system the (mental) functions and processes are embodied in terms of rules representing facts about the world. In addition, when hitting upon impasses, the rather inadequate robot-like learning (or chunking) mechanism operates by building new rules based on existing ones, most of which were initially presented as knowledge to the system from the outside in a ready-made form. Inadvertently some required intelligence is inserted into the model by hand. Thus, it is clear that such a limited rule-based system cannot assist traffic engineers and psychologists in their quest to significantly advance the understanding and mimicking of humanlike rationality and learning, not to mention other crucial and untouched domains of human cognition (for example, perception, attention, forgetting, and error proneness), emotions, and motor control impacting on driver behaviour.

2.2.9 Conclusions

Rules which describe externally observable behaviour and rules which determine the functional relations which generate such behaviour tend to be confused or combined indiscriminately in various contemporary models. Using a rule which describes observable behaviour as a shorthand expression for internal information processing brings with it the risk of infesting one's processing model with pernicious homunculi or vicious circles – technically speaking one is putting the explanandum in the explanans (Michon, 1989). Rule-based systems, such as Soar, may seem to conform to a central principle of making a clear distinction between these two types of rules, thus somehow reducing the risk that one is inadvertently inserting the required intelligence into the model by hand. However, such systems fall short of even explaining humanlike rational reasoning and learning, and, without touching on issues of stimulus processing, attention, memory retrieval, emotions, and motor control, should be dismissed.

CHAPTER 3

TOWARDS AN EXTENDED BASIS FOR UNDERSTANDING AND MODELLING DRIVER BEHAVIOUR

3.1 Robot-like or Human Behaviour

Michon (1985) proposed to head for an intelligent, knowledge and rule-based model of the driver capable of dealing with a wide variety of realistic, complex situations, or, as he stated, a psychologically plausible expert system. By choosing a rule-based architecture, as proposed, it would seem as if an architecture suited for the development of an intelligent robot has to be thwarted in order to exhibit humanlike behaviour. This can be another pitfall similar to the functionalistic modelling principle discussed previously of making a clear distinction between rules which describe externally observable behaviour and rules which determine the functional relations which generate such behaviour. Specifically, it is essential to discriminate between wishing to design a robot-like controller required to negotiate a road network, shared with or without human drivers, in a safe and optimised (and perhaps a humanlike) manner; or, on the other hand, the quest of better understanding the interacting and underlying mechanisms shaping the behaviour of an individual driver as part of human behaviour in general. Like in the case of general science, it follows that the level of detailed knowledge of only the latter will determine, for example, the strength and rate of success of driver education and training programmes to foster proper road sense or to manipulate and alter different aberrant behaviours of individual drivers. In addition, such an understanding will assist engineers and psychologists in explaining and modelling what humans actually do while exposed to various traffic environments as opposed to what humans are capable of doing.

3.2 Applying Models of Cognition

According to Michon (1985), there appeared to be a lack of new ideas in driver behaviour modelling in the 1980s, as it seems to be also the case today (2002). In his paper, Michon had to answer the double question: 'What do we know, and what should we do?' An analysis led him to the conclusion that human factors research in the area of driver behaviour has hardly been touched by the 'cognitive revolution' which swept psychology in the fifteen years prior to 1985, dethroning the behaviourists and restoring the inner states of mind as appropriate topics. Throughout much of the first half of the twentieth century, psychology was dominated by behaviourists, who believed that the subjective inner states of mind, like perceptions, memories and emotions, are not appropriate topics for psychology (Skinner, 1938).

However, more than a decade after Michon's paper, traffic researchers seemingly have embarked upon investigating the application of architectures integrating cognitive and perceptual-motor processes in models of task and attention management (for example, Salvucci et al., 2001). The field to study rationality, known as cognitive science, tries to understand how people come to know their world and use their knowledge to live in it. It asks how people recognise a certain pattern of visual stimulation falling on the retina as a particular object, say an apple, or determine the apple's colour, or judge which of two apples is bigger. It seems that humans are different from other animals very largely due to the far greater richness of humans' cognitive processes. Associated with memory of individual events and sophisticated generalisations, these processes allow subtle analogies and explanations – and the ability to draw pictures and speak and write. Cognitive science is often described as the 'new science of mind' (Gardner, 1987), however, it is a science of only a part of the mind, the part having to do with thinking, reasoning, and intellect, as emotions are not been taken into account.

3.3 Functionalism and Current Models of Cognition

Functionalism is the idea enshrined in the old proverb – handsome is as handsome does. Matter matters only because of what matter can do. Functionalism in this broadest sense is so ubiquitous in science that it is tantamount to a reigning presumption of all of science. And since, in science, there has always been searched for simplifications, looking for the greatest generality which can be mustered, functionalism in practice has a bias in favour of minimalism, of stating that less matters than one might have thought. For example, the law of gravity states that it does not matter what material an object consists of – only its mass matters (and its density, except in a vacuum). The trajectory of cannonballs of equal mass and density is not affected by whether they are made of iron, copper or gold. It might have mattered, one imagines, but in fact it does not. And wings do not have to be covered with feathers in order to power flight, and eyes do not have to be blue or brown in order to see. Every eye has many more properties than are needed for sight, and it is science's job to find the maximally general, maximally non-committal – hence minimal – characterisation of whatever power or capacity is under consideration. Not surprisingly, then, many of the disputes in science concern the issue of whether or not one school of thought has reached too far in its quest for generality (Dennett, 2001).

Since the earliest days of cognitive science, there has been a particularly bold kind of functionalistic minimalism in contention, the idea that just as a heart is basically a pump, and could in principle be made of anything so long as it did the requisite pumping without damaging the blood, so a mind is fundamentally a control system, implemented in fact by the organic brain, but anything else which could compute the same control functions would serve as well. The actual make-up of the brain – for example, the chemistry of synapses, and the role of calcium in the depolarisation of nerve fibres – is roughly as irrelevant as the chemical composition of the cannonballs mentioned earlier. According to this tempting proposal, even the underlying micro-architecture of the connections within the brain can be ignored for many purposes, at least for the time being, since it has been proven by computer scientists that any function that can be computed by one specific computational architecture can also be computed (perhaps much less efficiently) by another architecture. If all that matters is the computation, one can ignore the wiring diagram of the brain, and its chemistry, and just be concerned about the 'software' running on it (Dennett, 2001).

This bold vision, computationalism or 'strong AI' (Searle, 1980), is composed of two parts: the broad creed of functionalism – handsome is as handsome does – and a specific set of minimalist empirical wagers: neuroanatomy doesn't matter; chemistry doesn't matter. This second theme excused many would-be cognitive scientists from educating themselves in these fields, for the same reason that economists are excused from knowing anything about the metallurgy of coinage, or the chemistry of the ink and paper used in bills of sale. This has been a good idea in many ways, but for fairly obvious reasons it has not been a politically astute ideology, since it has threatened to relegate those scientists who devote their lives to functional neuroanatomy and neurochemistry, for instance, to relatively minor roles as electricians and plumbers in the grand project of explaining human behaviour. However, the recent history of neuroscience can be seen as a series of triumphs for the advocates of detail. Yes, the specific geometry of the connectivity matters; yes, the location of specific neuromodulators and their effects matter; yes, the architecture matters; yes, the fine temporal rhythms of the spiking patterns matter, and so forth. Many of the fond hopes of opportunistic minimalists have been dashed: they had hoped they could leave out various things, and they have learned that no, if one leaves out x, or y, or z, one cannot explain how the mind actually works (Dennett, 2001).

This has left the mistaken impression in some quarters that the underlying idea of functionalism has been flawed. On the contrary, the reasons for accepting these new claims are precisely the reasons of functionalism. Neurochemistry matters because – and only because – it has been discovered that the many different neuromodulators and other chemical messengers which diffuse through the brain have functional roles bringing about important differences. What those molecules do, turns out to be important to the computational roles played by the neurons, so one has to pay attention to them after all (Dennett, 2001).

3.4 Towards a Neural Basis for Models of Cognition

Hebb (1949) put forward the case for basing models of cognitive functions on what is known about the physiology of the brain, enabling the anatomist, physiologist and neurologist to contribute to psychological theory. Hebb thought that it would help psychological theorising if there is an input from neurophysiology. However, some researchers maintain that neurophysiological plausibility is irrelevant to psychological theorising and that the gap between knowledge of what brain structure is and how it produces behaviour is so wide that any endeavour to make psychological theories neuronally plausible is at best unhelpful, and at worst positively misleading (McLeod et al., 1998). Furthermore, Churchland and Sejnowski (1990), reacting to the functionalism that the mind can be modelled independent of knowledge of how the brain works, have argued that nature is more ingenious than humans are. Humanity stands to miss all that power and ingenuity unless neurobiological plausibility is attended to. The point is, it has already been done in nature, so why not learn how that stupendous machine, the human brain, actually works? It should be clear that opposition against vigorously incorporating up-to-date advances in the neurosciences will constantly hamper valuable progress on a wide front in the behavioural sciences.

Fortunately, in the last decade or so there has been an ongoing revolution in the understanding of how the human brain, primarily involved in cognitive behaviour, given streams of input from a structured world by its sensory receptors, can perform functions and learn novel facts in a humanlike manner by means of a system which computes with simple neuron-like elements, acting in parallel (McLeod et al., 1998). The investigation of what can be achieved by models which perform parallel distributed processing is called connectionism.

Despite the complexity of the behaviour they can simulate, the principles on which connectionist models are based are simple. These are derived from observations of the organisation of information processing in the brain:

a) The basic computational operation in the brain involves one neuron passing information related to the sum of the signals reaching it to other neurons.
b) Learning changes the strength of the connections between neurons and thus the influence that one has on another.
c) Cognitive processes involve the basic computation being performed in parallel by large numbers of neurons.
d) Information, whether about an incoming signal or representing the memory of the network of past events, is distributed across many neurons and many connections. There is no one

> place where a particular piece of knowledge can be located. All the knowledge that the network contains is superimposed on the same set of connections. All the processing that the network can do is determined by the same set of connections.

Since the central principles of connectionist models are derived from current knowledge of computation within the brain, the models are said to be 'neurally inspired'. This puts them in stark contrast to traditional models in cognitive psychology or artificial intelligence (AI). Traditional models in cognitive psychology contain elements like limited capacity channels, articulatory loops and short-term memory stores. Models in AI contain sets of rules. Either approach allows modelling of human cognitive capacities, but in general no attempt is made to relate the operations these elements perform to the way the brain works at a neuronal level. The aim of a traditional model is to describe the performance of the subject, not the way that the performance is achieved. The connectionist approach is the reverse. It starts with a model which incorporates brain-like processing and sees whether behaviour emerges, which mimics that shown by people (McLeod et al., 1998).

Since the brain does compute with neurons it might seem to go without saying that neural plausibility is a virtue in modelling cognitive processes. Nevertheless, there are some drawbacks to this approach. Researchers do not have a complete understanding of the way that information is transmitted between neurons in the brain. The method of passing information from neuron to neuron in connectionist models certainly occurs, at least at a conceptual level. However, in the brain there are other methods of inter-neuronal signalling which are not yet implemented in connectionist models. Also, some connectionist models contain procedures, especially learning algorithms, which are at present believed not to occur in the brain. But, the important point is that completely accurate neural models may be possible in the future. At the moment neural plausibility is a relative rather than an absolute virtue. Contemporary connectionist models are based on the assumption that although they make simplifications, they can provide a useful starting point for understanding how cognitive computations might be performed.

In most connectionist models the overall structure has not been related to any particular brain area. Nevertheless, sufficient quantitative information exists about the structure of certain brain areas, and the flow of information to and from them, to build neural network models which have structural as well as neuronal plausibility. Examples include a model of episodic memory formation which has a structure based on the hippocampal system, and a model of visual object recognition which is based on the organisation of information processing in one of the visual pathways in the primate brain. These models involve brain-like learning mechanisms of pattern association, autoassociation, and competitive learning. It is important to note that, through these modelling studies, major progress is being made in understanding how the hippocampus works as part of the brain's system for memory formation. An implementable quantitative model like this allows more than just showing that a particular approach to implementing brain function works. It allows one to see how performance changes as various aspects of the simulation are changed. Thus, a clearer view of how parts of the system contribute to the performance of the whole can be obtained (McLeod et al., 1998).

Fundamental to the classical view of cognition is the existence of discrete symbolic entities, representing possible states of the world. On this view cognitive activity involves the manipulation of these symbols by rules. The interaction of symbols and rules to produce thought can be seen as similar to the interaction between words and syntax which produces language. The problem with connectionism, on this view, is that distributed representations of propositions lack the internal structure necessary to permit rule-governed transformations. Fodor and Pylyshyn (1988) argue that this counts decisively against connectionist approaches to cognition – aspects of mental processes which they referred to as their systematicity and compositionality. However, networks with recurrent connections can form basins of attraction so that inputs within a given range will eventually settle on an identical output. Different attractor basins capture different sets of inputs. To the extent that attractor basins are insensitive to small variations in input, they could be considered to have a symbolic quality. Rule-governed behaviour might be the trajectory through a series of attractor basins which a network passes through in performing a task such as processing a sentence.

One argument against the connectionist approach is not to deny that cognition is carried out by neural networks in the brain, but to say that studying them is pointless. The networks merely implement rules and symbols in a somewhat opaque way. If one is interested in rule and symbols one should study them directly. A possible counter to this is that although one can study the rules and symbols directly one will never discover anything more than what they are. The connectionist approach may possibly show why they are as they are. For example, a minority default rule could be learnt in a language with one distribution of words and not in a language with a different one. At the level of rules this would just be a fact; at the level of a connectionist model one can see why. The relative merits of the traditional and connectionist approaches to cognition are affected by what different people see as a plausible scientific theory of the mind.

Another insight, which stems from connectionist modelling, concerns the separation of the 'what' and 'where' channels, as observed in the primate visual system. One can reasonably ask how the brain networks got to be that way. One answer has been to propose that organisms come equipped with a range of expert networks that possess specialised computational capacities. Tasks are co-opted by the specialist networks depending on the suitability of their computational properties for the task at hand. Jacobs et al. (1991) have shown how mixtures of expert networks exposed to a 'what/where' problem will always assign the 'where' task to the expert network which possesses a linear activation function. The implication is that networks do not necessarily need to be designed to carry out particular tasks. Rather, the task will select the network which has the appropriate (or innate) computational properties.

In addition, connectionist modelling of past tense acquisition by children shows that inferring dissociations in mechanism from dissociations in behaviour (in this case, performance on regular versus irregular verbs) is hazardous. It is not necessary to invoke a separate symbolic system to explain the processing of regular verbs. For example, the model by Plunkett and Marchman (1993) demonstrates how patterns of regularity and irregularity might be represented in a cognitive system without appealing to an innate pre-wiring of the system. The model challenges the orthodoxy that learning a language consists of learning a system of symbolic rules. Of prime importance to developmentalists is the demonstration that a homogenous computational system can learn to perform a complex task which was thought to require a heterogeneous architecture. The model demonstrates that one does not need as much pre-wired, innate structure to learn the past tense as the dual-route approach in psychology supposes (McLeod et al., 1998).

The fact that a multi-layered network can perform the task does not prove that children use the same type of mechanism – only that they might. Evaluation of the plausibility of the model rests on its behavioural predictions. Connectionist models are slaves to their training environments. Their performance reflects the distribution of examples they encounter. For example, current connectionist models predict that the onset of over-regularisation errors, heralding the discovery of the regularities underlying the inflectional system, is closely yoked to the achievement of a critical mass of regular verbs in the child's vocabulary. A critical mass effect in children acquiring the English past tense has been demonstrated by Plunkett and Marchman (1996). Connectionist modelling of development provides the researcher with a tool for examining the trade-off between initial architectural and computational constraints on the one hand and environmental information on the other.

An appealing aspect of the connectionist approach is that the models of cognitive processes are computational. That is, they actually produce a response to a stimulus. The predictions that such models make about reaction time or error rate or interference can be compared at a quantitative level to the behaviour produced by subjects in experiments. The inability of many traditional models of cognitive processes to do more than make qualitative predictions about the effect of some experimental variable on performance has often made it difficult to choose between them because they make the same qualitative prediction. Connectionist models have given a precise match to data obtained in experiments with human subjects. Connectionist simulations do not just mimic results which are already known. Their predictions have suggested fruitful areas for experimentalists to investigate (McLeod et al., 1998). Therefore, to mimic human behaviour it would be advantageous to base modelling on a system architecture relating operations such as stimulus processing, learning, memory retrieval, and motor control to the way the brain functions at neuronal level. Thereby it can be ensured that the 'required' and 'appropriate' intelligence and learning mechanisms are built into the model.

3.5 Importance of Emotion and Consciousness alongside Cognition in Modelling

According to psychologists, stress results when the perceived demands of the driving task are appraised as exceeding the driver's ability to cope with them. There are marked individual differences in self-reported susceptibility to stress during driving. General driver stress is associated with higher levels of neuroticism, aggression-hostility, emotional reactions to overtaking and being overtaken, frequency of everyday hassles, self-rated poor concentration and absentmindedness, and with stressed mood. Furthermore, involvement in automobile accidents is correlated with an insufficiency in the ability to control changes in emotion, emotional lability and excessive dependence on environmental stimuli.

Interestingly, McEwen (1992) has shown that severe but temporary stress can result in a shrivelling up of dendrites in the hippocampus of an animal. Dendrites are the parts of neurons which receive incoming inputs and which are responsible, in large part, for the initial phases of long-term potentiation and memory formation (Koch et al., 1992). McEwen has also shown that if the stress is discontinued, these changes are reversible. However, with prolonged stress, irreversible changes take place. Cells in the hippocampus actually begin to degenerate. When this happens, the memory loss is permanent. Recent studies have specifically shown that the human hippocampus is vulnerable to stress (Bremner et al, 1995).

Another key issue in applied social psychology research deals with the effectiveness of fear-arousing messages for changing attitudes and behaviours. A persuasive message presenting a person with the possibility that he/she is at risk with regard to the occurrence of an aversive event is effective in changing his/her behaviour. The fear aroused by a threatening message leads the person to mentally and behaviourally rehearse recommended actions to avoid the danger and thus reduce the fear. Threat appeals have been used for many years as the main mean to foster careful driving-related attitudes and behaviours. These appeals usually consist of road-trauma films, showing crashed cars, bereaved parents, or injured people who were involved in car accidents. The goal of these appeals is to elicit fear and to remind people of their own vulnerability and finitude while driving in a reckless manner. However, there are opposing views on the effectiveness of driving-related threat appeals.

In short, driving has become intolerably stressful, dangerous, and demeaning. Drivers are stressed, threaten each other, are in a bad mood, terrorise their passengers, and often fantasise violent acts against each other. Emotions are as much traffic and transportation issues as cognitive functions, road conditions and traffic flow are in a comprehensive transportation model.

Understanding emotions in the human brain is clearly an important quest, as most mental disorders are emotional disorders. Emotions are biological functions of the nervous system which is in itself an enormously rich source of variables to manipulate. Figuring out how emotions are represented in the brain, greatly expand opportunities for making new discoveries beyond what can be achieved with psychological experimentation alone, and can help people understand them. This approach contrasts sharply with the more typical one in which emotions are studied as psychological states, independent of the underlying brain mechanisms. Psychological research has been extremely valuable, but an approach where emotions are studied as brain functions is far more powerful. Additionally, studying the way emotion (and cognition) works in the brain can help to choose between alternative psychological hypotheses – there are many possible solutions to the question of how emotions (and cognitions) might work, but the only relevant one (in understanding human behaviour) is the solution which was put into the brain with creation (LeDoux, 1998).

Therefore, according to LeDoux, the proper level of analysis of a psychological function is the level at which that function is represented in the brain. This leads to a conclusion that the word ‘emotion’ does not refer to something that the mind or brain really has or does. ‘Emotion’ is only a label, a convenient way of talking about aspects of the brain and the mind. Psychology often carves the mind up into functional pieces, such as perception, memory and emotion. These are useful for organising information into general areas of research but do not refer to real functions. The brain, for example, does not have a system dedicated to perception. The word ‘perception’ describes in a general way what goes on in a number of specific neural systems – humans see, hear and smell the world with their visual, auditory and olfactory systems. In a similar vein, the various classes of emotions are mediated by separate neural systems. There is no such thing as the ‘emotion’ faculty and there is no single brain system dedicated to this function.

Ongoing research is rapidly advancing understanding about how the brain detects and responds to emotionally arousing stimuli, how emotional learning occurs and emotional memories are formed, and how conscious emotional feelings emerge from unconscious processes. When these neural systems function in a human with conscious awareness, then conscious emotional feelings occur. Emotional responses, for example, trembling, sweating, and heart palpitations are, for the most part, generated unconsciously.

Conscious feelings, like the feeling of being afraid, or angry, or happy, or disgusted, are in one sense no different from other states of consciousness, such as the awareness that a roundish, reddish object is an apple, that a sentence just heard was spoken in a particular foreign language, or that one has just solved a previously insoluble problem in mathematics. States of consciousness occur when the system responsible for awareness becomes privy to the activity occurring in unconscious processing systems. What differs between the state of being afraid and the state of perceiving red is not the system which represents the conscious content (fear or redness) but the systems that provide the inputs to the system of awareness. There is but one mechanism of consciousness and it can be occupied by mundane facts or highly charged emotions. Emotions easily bump mundane events out of awareness, but non-emotional events (like thoughts) do not so easily displace emotions from consciousness.

Emotions are things which happen to people rather than things people will to occur. Although people set up situations to modulate their emotions all the time (for example, going to movies and amusement parks, or consuming alcohol and other recreational drugs), in these situations, external events are simply arranged so that the stimuli which automatically trigger emotions will be present. People have little direct control over their emotional reactions. While conscious control over emotions is weak, emotions can flood consciousness, because the wiring of the brain is such that connections from the emotional systems to the cognitive systems are stronger than vice versa. Once emotions occur they become powerful motivators of future behaviours, setting the course of both moment-to-moment action as well as towards long-term achievements. Emotions can have both useful and pathological consequences. When fear becomes anxiety, desire gives way to greed, or annoyance turns to anger, anger to hatred, friendship to envy, or pleasure to addiction, emotions start working against people.

The study of emotion has been ignored by the field of cognitive science, the major scientific enterprise currently concerned with the nature of the mind. As cognitive scientists treat minds as information-processing devices, they have traditionally been more interested in how people and machines solve logical problems than in why people are sometimes emotional. This shortcoming has been corrected in an unfortunate way – by redefining emotions as cold cognitive processes, stripping them of their passionate qualities. At the same time though, cognitive science has been very successful and has provided a framework that, when appropriately applied, provides an immensely valuable approach for pursuing the emotional as well as the cognitive mind. One of the major conclusions about cognition and emotion, which comes from this approach, is that both seem to operate unconsciously, with only the outcome of cognitive or emotional processing entering consciousness and only in some instances. Just as one can study how the brain processes information unconsciously in perceiving visual stimuli and using visual information to guide behaviour, one can study how the brain processes the emotional significance of stimuli unconsciously and uses this information to control behaviours appropriate to the emotional meaning of the stimuli.

Cognitive scientists tend to think of the mind in terms of the functional organisation of unconscious processes which underlie and give rise to mental events, rather than conscious contents which occur during and as a result of the processing (Neisser, 1976). These processes span many levels of mental complexity, from the routine analysis of the physical features of stimuli by sensory systems, to remembrance of past events, to speaking grammatically, to imagining things which are not present, to decision-making and beyond. As Lashley (1950) pointed out, conscious content comes from processing, and humans are never consciously aware of the processing itself but only of the outcome. Gazzaniga and LeDoux (1978) were engaged in studies of split-brain patients which led them to similar conclusions. It can be concluded that people normally do all sorts of things for reasons they are not consciously aware of (because the behaviour is produced by brain systems that operate unconsciously) and that one of the main functions of consciousness is to keep people's lives tied together into a coherent story, a self-concept. It does this by generating explanations of behaviour on the basis of self-image, memories of the past, expectations of the future, the present social situation and the physical environment in which the behaviour is produced (Gazzaniga, 1988).

It seems clear that much of mental life occurs outside of conscious awareness. People can have introspective access to the outcome of processing (in the form of conscious content), but not all processing gives rise to conscious content. Stimulus processing which does not reach awareness, in the form of conscious content, can nevertheless be stored implicitly or unconsciously and have important influences on thought and behaviour at some later time (Bowers and Meichenbaim, 1984; Bargh, 1992). Furthermore, information can be simultaneously processed separately by systems that do and do not give rise to conscious content, leading to the conscious representation in some and the unconscious representation in other systems. That much of the processing involved in these functions occurs unconsciously has allowed cognitive science a luxury that earlier forms of mentalism did not have – the field could get on with the business of studying the mind without having to first solve the problem of consciousness (Churchland, 1984). In fact, it is probably true that consciousness will only be understood by studying the unconscious processes which make it possible.

What is it about emotion that has compelled cognitive scientists to separate it out from attention, perception, memory and other bona fide cognitive processes? Why was emotion excluded from the rehabilitation of the mind which took place with the cognitive revolution in psychology? When the computer metaphor was developed, it was seen as more applicable to logical reasoning processes than to so-called illogical emotions. However, cognition is not as logical as it was once thought and emotions are not always so illogical. Success in life, according to Goleman (1995), depends on a high EQ (emotional quotient) as much or more than a high IQ. It is true that derailed emotions can lead to irrational and even pathological consequences, but emotions themselves are not necessarily irrational.

Fortunately, some cognitive scientists have recognised that emotion is important. Simon (1967), for example, argues that cognitive models need to account for emotions in order to approximate real minds. These suggestions by leading cognitive scientists have finally begun to have an impact – more and more cognitive scientists are getting interested in emotions. While early AI programmes were most successful at modelling logical processes, more recent models have gone far beyond this truly artificial approach and some try to model aspects of emotions. Some programmes use emotional 'scripts' or 'schemas' as aids to decision making and action, others try to simulate the processes through which people evaluate or appraise the emotional meanings of stimuli, and still others attempt to make use of the understanding of the emotional brain in order to model how emotions are processed (Dyer, 1987; Scherer, 1993b; Frijda and Swagerman, 1987; Sloman, 1987; Armony et al., 1995). The logical/illogical or rational/irrational distinction is not very sharp when it comes to separating emotion and cognition, and certainly not a clean way of defining what a science of mind should be about.

The functionalist conception of mind as a programme that can run on any machine (mechanical, electronic, biological) has been easy to accept, or at least tolerate, in the area of cognition. The biological machine of relevance to cognition, of course, is the brain. The idea that the brain is a cognitive computer is now commonplace. However, in emotions, unlike in cognitions, the brain does not usually function independently of the body. Many if not most emotions involve bodily responses. No such relation exists between cognitions and actions. In the case of cognitively driven responses, the response is arbitrarily linked to cognition. This is partly why cognition is so powerful – cognitions allow people to be flexible, and to choose how they will respond in a certain situation. If the biological machine of emotion, but not cognition, crucially includes the body, then the kind of machine that is needed to run emotion is different from the kind needed to run cognition.

Even if the functionalist argument (that the hardware is irrelevant) could be accepted for mind as cognition (and it is not clear that it can), it would not seem to work for the emotional aspects of the mind (since the hardware does seem to make a difference when it comes to emotion).

Programming a computer to be conscious would be an essential first step towards programming it to have a full-blown emotional experience, since the feelings through which people know their emotions occur when they become conscious of the unconscious workings of emotional systems in the brain. However, even if a computer could be programmed to be conscious, it is not guaranteed that it could be programmed to have an emotion, as a computer does not have the right kind of composition, which does not come from the clever assembly of human artefacts but a specialised biological creation. For LeDoux it seems impossible that a full-blooded emotional feeling could exist without a body attached to the brain which is trying to have the feeling. Bodily feedback needed entails somatic and visceral information which returns to the brain during an act of emotional responding.

Emotion and cognition are best thought of as separate but interacting mental functions mediated by separate but interacting brain systems (LeDoux, 1998):

a) The perceptual (cognitive) representation of an object and the evaluation of the significance of an object are separately processed by the brain.
b) The emotional meaning of a stimulus can begin to be appraised by the brain before the perceptual systems have fully processed the stimulus.
c) The brain mechanisms through which memories of the emotional significance of stimuli are registered, stored and retrieved are different from the mechanisms through which cognitive memories of the same stimuli are processed.
d) The systems that perform emotional appraisals are directly connected with systems involved in the control of emotional responses. Once an appraisal is made by these systems, responses occur automatically. In contrast, systems involved in cognitive processing are not so tightly coupled with response control systems. The hallmark of cognitive processing is flexibility of responses on the basis of processing. Cognition gives people choices.
e) The linkage of appraisal mechanisms with response control systems means that when the appraisal mechanism detects a significant event, the programming and often the execution of a set of appropriate responses will occur. The net result is that bodily sensations often accompany appraisals and when they do they are a part of the conscious experience of emotions. Because cognitive processing is not linked up with responses in this obligatory way, intense bodily sensations are less likely to occur in association with mere thoughts.

An emotion is not merely a collection of thoughts about situations. It is not simply reasoning and cannot be understood by just asking people what went on in their minds when they had an emotion. Emotions are notoriously difficult to verbalise since they operate in a neural space which is not readily accessed from consciousness. Psychiatrists' and psychologists' offices are kept packed for this reason. Still, much of the understanding of the way the emotional mind works has been based on studies which have used verbal stimuli as the gateway to emotions or verbal reports to measure emotions. In contrast to consciousness and its associate, natural language, unconscious processing is the rule rather than the exception throughout the creation. Moreover, in the unconscious mental realm nonverbal processing is the standard. Given that so much work on unconscious processing (cognitive and emotional) has focused on verbal processes, the picture of the level of sophistication of unconscious processes in humans is probably highly inaccurate. The workings of human unconscious processes will only be fully understood once the use of verbal stimuli and verbal reports is phased out (LeDoux, 1998).

LeDoux's idea about the nature of conscious emotional experiences and feelings constitutes that a subjective emotional experience, like the feeling of being afraid, results when one becomes consciously aware that an emotion system of the brain, like the defence system, is active. Emotional experience is not a problem about emotion. Instead it is a problem about how conscious experiences occur. Emotions researchers certainly have a lot to contribute to the study of consciousness, but figuring out consciousness is not their job, or at least theirs alone. Although this may seem obvious, the study of emotion has been so focused on the problem of emotional consciousness that the basic underlying emotional mechanisms have often been given short shrift. By treating emotions as unconscious processes which can sometimes give rise to conscious content, the burden of the mind-body problem is lifted from the shoulders of emotion researchers and allow them to continue with the problem of figuring out the unconscious emotional functioning of the brain. In order to understand what an emotion is and how particular emotional feelings come about one needs to understand the way the specialised emotion systems operate and determine how their activity gets represented in the system which gives rise to consciousness.

Conscious emotional feelings and conscious thoughts are in some sense very similar. Both involve the symbolic representation in consciousness of sub-symbolic processes carried out by systems which function unconsciously. However, the difference between them is not due to the system concerned with consciousness. Emotional feelings and mere thoughts are generated by different sub-symbolic systems, while emotional feelings involve many more brain systems than thoughts (cognition).

3.6 Brain Development – the Role of Neurobiochemical Processes and Environmental Influences

According to Squire and Kandel (2000) people are not who they are simply because they think. People are who they are because they can remember what they have thought about. Understanding the ways in which early experiences influence how people remember, how they make connections to others, the ways in which they feel and create internal models of the world, and the manner in which they learn to organise their sense of self each should be understood from a common, synthetic view. Siegel (1999) explores the ways in people connect with others and themselves through their relationships, emotions, and the stories of their lives and puts forward a way of seeing one's life and relationships with others from a perspective that shows how one's mind is created from a combination of brain processes ('neurobiology') and one's relationships with other people ('interpersonal').

The principles of how stimuli and genes act together to control brain differentiation are beginning to come to light. When embryo nerve cells migrate and form into patterned aggregates, and when they grow long, branching axons which sort themselves in an intricate criss-crossing array to make up patterned circuits, they communicate by biochemical expressions of regulator genes, switching the actions of other genes governing nerve cell development. Once the network of nerve connections is formed, another factor, conduction of nerve impulses, adds power and precision to this communication. The phenomenon whereby the neighbourhood relationships of cells in one set are maintained in the connection pattern formed with the other set, is common within the nervous system. It is known that many of the functions of the nervous system depend on the existence of these orderly mappings. The brain is seen to lay the foundations of even the higher psychological processes before birth. The way the human brain parts grow before birth suggests that the interacting nerve cells might make up and coordinate basic rules for object perception, purposeful movement patterns, and for motive states, mostly without the benefit of experience. This is confirmed by the behaviour of infants shortly after they are born.

One is therefore obliged to pay careful attention to the steps by which nerve cells are linked up into communicating systems, as brain growth is inseparable from mental growth. It is important to note that the facts of brain growth do not imply that mental and physical abilities governed by the brain simply expand and elaborate independently of stimuli, nor do they give the brain a passive submissiveness to experience (Gregory, 1987). Furthermore, studies emphasise the capacity (which remains even into adulthood) for reorganising the structure and function of cortical maps (even the organisation of action) as the result of injury or of particular kinds of experience. The effects of experience on the brain can be viewed as a continued elaboration of the developmental programme.

It is now clear that the anatomy and function of human cerebral cortices are very variable. People differ in the pattern of their mental abilities because their brains grow in different forms. Some of this diversity of human minds will be pre-programmed in a great variety of outcomes of gene expression in nerve tissue development, but the same brain processes are also influenced by foetal and postnatal environments. In future research, brain science will be concerned with breaking through the veil of ignorance which still conceals how developments in human brain tissue over the years of childhood relate to psychological maturation. In this phenomenon, unique in developmental biology, the state of morphogenetic regulators in an immature organism depends upon the affections and interests of more mature conscious beings, and upon the way the brains of these beings from the preceding generation have been programmed with cultural rituals and beliefs in an earlier childhood. Growing human brains require cultivation by intimate communication with older human brains. Thus are built the powerful collaborations of human society (Gregory, 1987).

To summarise, infants are born with a number of primitive tendencies and sensory limitations which constrain the possible developmental paths that can be taken by powerful perceptual and cognitive learning systems. Further, because only parts of the adult cognitive system are in place during early infancy, and certain brain pathways and structures are slower than others to develop, the study of infants offers one a unique opportunity to unravel how complex hierarchical and parallel competing brain pathways give rise to adult cognition. The study of infancy is thus central to significant further progress in the neurosciences (Johnson, 1994). In the same vein, Schore (1999) argues for the rapprochement between neurobiology and psychoanalysis, to bring together neurobiology, developmental neurochemistry, behavioural neurology, evolutionary biology, developmental psychology, developmental psychoanalysis and infant psychiatry. Schore's central thesis is that 'the early social environment, mediated by the primary caregiver, directly influences the evolution of structures in the brain responsible for the future socio-emotional development of the child'. It is of vital importance to keep all these aspects of brain development in mind when one, for example, sets out to understand and model the behaviour of a learner driver, or the changes in behaviour over the lifetime of a driver. For example, just consider how long the neural circuitry of an individual's brain will have been exposed to the shaping effects of the environment by the time he/she applies for a learner permit at, for say, the age of sixteen.

There is no denying that genes make humans different from one another and explain at least part of the variability in the way different people act in situations. However, one has to be very careful in interpreting differences in behaviour between different people. Dawkins (1982) states that if a person is homozygous for a gene G, nothing save mutation can prevent passing G on to all his/her children. So much is inexorable, but whether or not the person, or his/her children, show the phenotypic effect normally associated with possession of G may depend very much on how they are brought up, what diet or education they experience and what other genes they happen to possess. People's separation into haves and have-nots, weak and strong, and other such categories is more often than not a product of cultural evolution, a process far more complex than the mere mutation and adaptation. According to Ehrlich (2000) genes 'do not shout commands to us about our behaviour; at the very most, they whisper suggestions'.

It can be concluded that genes give the raw materials out of which to put together brain functioning. They specify the kind of nervous system humans will have, the kinds of mental processes in which it can engage and the kinds of bodily functions it can control. However, the exact way humans act, think and feel in a particular situation is determined by many other factors and is not predestined in genes (Bateson and Martin, 2000). There exists a mistaken notion that science has discovered individual genes which determine certain personality traits. For example, some, if not many, emotions do have a biological basis, but social, which is to say cognitive, factors are also crucially important. Nature and nurture are partners in humans' emotional (and cognitive) life, and the difficulty is to figure what their unique contributions are.

What does it really mean to say that a behaviour is innate? Elman et al. (1996) describe a framework in which interactions, occurring at different levels, give rise to emergent forms and behaviours. These outcomes may often be highly constrained and universal, yet are not themselves directly contained in genes in any domain-specific way. They propose a taxonomy of ways in which a behaviour can be innate, including constraints at the levels of representation, architecture, and timing. Typically, behaviours arise through the interaction of constraints at several of these levels. These ideas have been explored through dynamic models inspired by a new kind of 'developmental connectionism,' a union of connectionist models and developmental neurobiology, forming a new theoretical framework for the study of behavioural development. While relying heavily on the conceptual and computational tools provided by connectionism, Elman et al. (1996) also identify ways in which these tools need to be enriched by closer attention to biology.

3.7 Social Cognition and the Human Brain

A 'Theory of Mind' (TOM) is a specific cognitive ability to understand other persons, and therefore other drivers, as intentional agents, that is, to interpret their minds in terms of theoretical concepts and intentional states such as beliefs and desires. It has been commonplace in philosophy to see this ability as intrinsically dependent upon linguistic abilities. After all, language provides people a representational medium for meaning and intentionality – thanks to language a person is able to describe other people's and his/her own actions in an intentional manner. According to this view, the intentionality of natural language, that is, the suitability for expressing meanings and thoughts, is the key for understanding the intentionality of a person's theory of mind.

However, a major challenge to this view came from studies on primate cognition and comparative psychology. Premack and Woodruff (1978) argued that experimental evidence of chimpanzees' understanding of human behaviour could be interpreted as detection of intentions. Although other primatologists have challenged their experimental data, there is growing evidence showing that non-human primates have some intentional understanding of their social world (Tomasello and Call, 1997). The presence of such capacity in non-human (and thus non-linguistic) species leads to the conclusion that it is possible to investigate TOM as a biological endowment independently of language.

Humans are exceedingly social beings, but the neural underpinnings of social cognition and behaviour are not well understood. Studies in humans and other primates have pointed to several structures which play a key role in guiding social behaviours. These structures appear to mediate between perceptual representations of socially relevant stimuli, such as the sight of conspecifics, and retrieval of knowledge (or elicitation of behaviours) which such stimuli can trigger. Current debates concern the extent to which social cognition draws upon processing specialised for social information, and the relative contributions made to social cognition by innate and acquired knowledge (Adolphs, 1999). Any total conception of the nervous system has to treat man as genetically endowed to function as a member of a group, with built-in drives and propensities to behave as humans are known to behave. To omit a person's relations with other members of the group is to leave out almost everything (Gregory, 1987).

Social cognition refers to the processes that subserve behaviour in response to conspecifics (other individuals of the same species), and, in particular, to those higher cognitive processes subserving the extremely diverse and flexible social behaviours which are seen in primates. Its evolution arose out of a complex and dynamic interplay between two opposing factors: on the one hand, groups can provide better security from predators, better mate choice, and more reliable food; on the other hand, mates and food are available also to competitors from within the group. An evolutionary approach to social cognition therefore predicts mechanisms for cooperativity, altruism, and other aspects of pro-social behaviour, as well as mechanisms for coercion, deception and manipulation of conspecifics (Adolphs, 1999). The former are exemplified in the smallest groups, in the bond between mother and infant; the latter in the largest groups by the creation of complex dominance hierarchies. Also, in studying the behaviour of a driver, as a contributor to the safety and effectiveness of a traffic system, the influences of these mechanisms will be apparent.

It is known that focal brain damage can result in impaired processing that is limited to highly specific categories. For instance, patients have been reported who are specifically unable to recognise, or to name, tools, animals, people, or a variety of other selective categories. There is thus very strong evidence that categories are, in some sense, mapped in the brain. The categories which are abstracted emerge naturally out of the covariances of people's interactions with certain classes of stimuli in the environment. Thus, people typically interact with members of the class of animals in a similar way; that is, the similarity is greater among animals than it is to how people typically interact with members of the class of tools, or members of the class of people. Similarity in sensorimotor interaction can thus translate into functional and anatomical similarity in the brain (Solomon et al., 1999).

The above view suggests a strong component of experience and learning in such self-organised topographic maps. A different explanation comes from the view that there are innately specified modules in the brain for processing specific categories of knowledge. The evidence for this latter view is strongest from domains such as language, and it is the view that has historically been associated with the notion of 'modularity' (Fodor, 1983). As with many dichotomies, it is likely that both views are right, in the proper context, and recent interpretations suggest a softer version of 'modularity' that does not require a rigid set of criteria (Coltheart, 1999). It may well be that there are domain-specific modules for processing certain kinds of information which are ecologically highly relevant and that would benefit from a particular, idiosyncratic processing strategy which does not apply to other kinds of information. That is, one would expect the brain to provide problem-specific structures for processing information from those domains in which there is a premium on speed and survival. Within, and beyond, such a module there might also be topographic mapping of the same domain. It is likely that domain-specific processing draws upon innately specified modules, as well as upon self-organised maps which emerged as a consequence of experience with the world (Adolphs, 1999).

Some rather basic attributes of stimuli, such as self-directed motion, bilateral symmetry, and presence of eyes might be processed similarly by different primate species, by mechanisms which are highly innately specified. However, there also seems little doubt that the class of social stimuli needs to be explored during development in order to be able to make more fine-grained distinctions – a development process which is likely to include behaviour of the supervisor and pretend play as critical aspects. The most plausible scenario, then, would view social cognition as relying on a neural architecture in which there is interaction between components which are innately specified and others whose operation emerges through experience in the context of a specific culture. For example, some classes of emotions, such as guilt, shame, embarrassment, and jealousy only make sense in a social context. Other social signals, and other types of social judgments, draw upon systems which subserve emotional processing in general, systems which permit people to build models of other individuals through simulation, and a vast network of structures which contribute to reasoning, inference and language. In fact, most of the neural structures known to be important to social cognition are also important to emotion, and to associating stimuli with reward and punishment (Adolphs, 1999).

3.8 Final Remarks

Very little has been done to determine what makes road users speed, drive while drunk, overtake, or yield at crossroads. The risk of accident involvement may be one motivational factor that plays a role, but there are clearly others which are equally important (Rothengatter, 1988b). If traffic engineers and psychologists are to be successful in modifying driver behaviour through education, publicity or enforcement activities, the identification of these underlying mechanisms is of primary importance. Unless models of driver behaviour are developed which take account of these mechanisms, modelling will not be able to accurately predict behaviour, and will offer very little guidance for developing measures aimed at influencing the behaviour involved. Unlike the researcher and the policy maker, road users have other things to worry about than accident statistics. In reality, the pluralistic motivations of different drivers and the dominance of satisficing behaviour characterise the driving scene.

Furthermore, traffic engineering and psychology carves driver behaviour up into functional pieces, such as risk perception, sensation seeking, and road rage. For example, the word 'risk perception' does not refer to something that an average driver, and for that matter his/her brain, does. These functional pieces are useful for organising information into general areas of research but do not refer to real functions. Not even a researcher interested in quantifying traffic risks has a system in his/her brain dedicated to risk perception. Psychological research has been extremely valuable and there is no denying of the validity and utility of observed driver behaviour documented in literature. However, an approach where driver behaviour is studied in terms of brain functioning is far more powerful and can help to choose between alternative psychological hypotheses. The proper level of analysis of a psychological function is the level at which that function is represented in the brain. Unless neurobiological plausibility is attended to, the functionalism that driver behaviour can be understood independent of knowledge of how the brain works, will needlessly waste precious time and effort on bitter controversies in future, as is evident from the protracted debate on risk homeostasis. To fuel these arguments, add careless and biased reading, and misinterpretations particularly from incomplete quotations.

From investigations of complex phenomena, such as learning and remembering tasks involving several of the senses, stem the view that the brain acts as a whole (Gregory, 1987). It is apparent that the driving task draws on a considerable number of human capabilities and functions, such as perception (vision, hearing, and touch), attention, memory (encoding and retrieval of procedural and declarative memory), motor control, language, and emotions. Furthermore, expert neural systems, specialised towards performing the mentioned functions, are all interdependent and interacting on various levels while impacting to a greater or lesser degree on the observed behaviours during the course of a drive, as studied by traffic psychologists, such as sensation seeking, speed choice, and passing manoeuvres. Therefore, it is important to realise that research on driver behaviour really necessitates studying the central nervous system as a whole. Implementation of a piece-meal set of models of different psychological paradigms seems to do disservice to the efficiency and remarkable unity of the brain in normal action (Taylor, 1999). It is also important that mental disorders (such as road rage and disregard for traffic laws), like mental order, reflect the workings of the brain (LeDoux, 1998). Understanding and modelling the complex world of the driver and driver error in an effective manner are thus no walk in the park – making it even more important to model on the solid and sound knowledge basis of brain functioning, a *raison d'être* of neuroscience.

As an example of interacting specialised networks consider the case of visual perception. In one simple view humans see by processing perceptual qualities such as form, colour and motion using independent modules. The organisation of the brain into processing streams (DeYoe and Van Essen, 1988) supports the idea that brain processing is specialised, but it does not imply that these streams contain independent modules. Independent modules should be able to fully compute their particular processes on their own. However, much perceptual data argue against the existence of independent modules, because strong interactions are known to occur between perceptual qualities (Egusa, 1983; Faubert and Von Grunau, 1995; Kanizsa, 1974; Pessoa et al., 1996; Smallman and McKee, 1995). For example, changes in perceived form or colour can cause changes in perceived motion, and vice versa; and changes in perceived brightness can cause changes in perceived depth, and vice versa (Grossberg, 2000).

In addition to the discussed advantages from explaining human (driver) behaviour in terms of brain activity, light could be shed on important side issues, such as the existence of extra-sensory perception (ESP). ESP refers to any 'mental faculty' which allows a person to acquire information about the world without the use of the known senses. Such 'faculties' are generally classified as (i) telepathy, (ii) clairvoyance, and (iii) precognition. A fourth phenomenon, psychokinesis, while not involving perception in the recognised meaning of the word, is almost always studied alongside ESP. Is there evidence that ESP exists? The non-materialistic view of the universe claims that it does. Despite the fact that it is scientifically unfashionable, it nevertheless commands wide support, even today, among the population at large. Given the limited understanding of the brain and mind presently, it is possible to support this view without being in any way irrational or unscientific, though most scientists would probably lean towards a more agnostic position (Gregory, 1987).

Establishing the reality of one or all of these faculties would be of great interest to anyone engaged in studying the brain and nervous system. Not only would strictly mechanistic models of psychology, such as those exemplified by Skinnerian behaviourism, have to be scrapped, but many of the assumptions and theories of physical science would need at least to be thoroughly overhauled. Clearly, if ESP exists, the idea of a non-materialistic component to the universe, with its own peculiar make-up, becomes more plausible. If the mind can roam more or less at will, then it would seem that man is, in part at any rate, a non-physical being, capable of exercising far greater control of his own destiny and of his environment than is usually assumed by science (Gregory, 1987).

Researchers are only just beginning to understand the workings of the brain, and attempts to explain man's innermost workings on the basis of physics, chemistry, and electricity make humans seem like extensions of the materialistic world. Few people want to have their 'souls stolen' from them so that they are no longer thought of living, caring, and vulnerable beings for whom beauty, art, music, and culture are more important than all things scientific. People even like it better when they think that they live in a universe full of mystery, with room for endless discoveries as well as endless delights (Dolphin, 1988). Biases like these, emergent from human brain activity, play a role when conducting driver behaviour studies since humans have to effectively study their own (frequently irrational) behaviour. According to Dolphin, scientists each bring their religious and philosophical presuppositions with them when they work in the lab – it is simply not possible to have science in a vacuum.

CHAPTER 4

A NEXT STEP: AN EXPERIMENTAL PLATFORM FOR FUTURE DRIVER BEHAVIOUR RESEARCH BASED ON THE INTEGRATION OF ENGINEERING AND NEUROSCIENTIFIC KNOW-HOW

4.1 Overview

State-of-the-art technologies within transportation engineering offer advanced capabilities for data and parameter measurement and extraction from driver behaviour experiments. A rich set of data can currently be obtained in such experiments performed in a simulator or instrumented vehicle, such as video and audio capturing, as well as spatial and temporal characteristics of objects forming part of the driving environment, especially those for the driver. Notwithstanding the diverse variety of data types available from driver behaviour experiments, data mining is essentially based on the underlying behaviouristic models presently applied in transportation engineering. This is in stark contrast to what has been an ongoing revolution in the understanding of how the human brain, given streams of input from a structured world by its sensory receptors, can perform functions and learn novel facts in a humanlike manner by means of a system which computes with simple neuron-like elements, acting in parallel. Thus, the neuroscientific approach, as set out in the previous chapter, is the reverse.

At the moment, the principal source of information on the global brain in action involves the discipline of functional brain imaging. Together with descriptions of the functions performed by the various brain areas, observed active while human subjects solve various tasks, these experimental paradigms are currently spearheading an attack on the modus operandi of the brain in toto. Thus, in order to align research on driver behaviour so that contemporary neuroscience can bear on the knowledge and understanding of such behaviour, a necessary step would be to incorporate brain-imaging devices into the sensor suite of driver behaviour experiments. *Accompanying the implementation of brain imaging, an imperative further step, needed to be taken by driver behaviour modellers, would be to develop neural network simulations which give overall agreement in activations with that observed in brain-imaging experiments.* These mentioned steps will contribute towards bringing driver behaviour research on par with the level of advanced knowledge on human behaviour offered in modern neuroscience, and introduce the well-instrumented and closely-monitored experimental platform offered by driver behaviour research into mainstream neuroscientific experimentation.

To illustrate the advances achievable in better understanding and modelling driver behaviour through integration of neuroscientific principles and know-how into driver behaviour experimentation, consider the issue of driver aggression and road rage from the field of transportation engineering. It is rather unfortunate that the focus of the aggressive driving issue has been almost exclusively on who are the aggressive drivers and what aggressive behaviours they display, rather than on why drivers in general are more aggressive now than before, and what can be done (not necessarily to the drivers) to ameliorate the situation. Research on aggressive driving to-date demonstrates that a significant amount of aggressive driving can probably be reduced by a careful, user-friendly, and ergonomically oriented design of the driving environment. Also, from an effective public health perspective the way to reduce road aggression should be to control the situations that give rise to it, rather than focus exclusively on driver education and mass media campaigns. However, before these results can be applied, they should be validated extensively. Apart from difficulties with present measures of aggression, much more data are needed on the relationship between environmental stimuli, individual differences and aggressive driving, before action oriented large-scale programs can be justified.

From research results, overt behaviours, such as affective (horn honking, vocalisations, and gesturing) and instrumental (acceleration) responses, currently employed in experiments, bring about concerns of reliability when employed as indicators for signalling driver frustration and aggression. In addition, consistent with knowledge from neuroscience, physiological responses do not correlate reliably with overt aggressive behaviours. Thus, despite efforts to provide a robust definition of aggressive driving, there remains a need for a more operational, useful, and commonly agreed-upon definition of aggressive driving. Taken together, the failure to observe the expected reliable relationships amongst aggression, overt behaviours, and visceral arousal raises questions about the soundness of the present experimentation paradigm.

In order to revitalise and advance not only research and the subsequent knowledge-base on driver aggression, but also on all other driver-related issues, the author proposes a shift towards the integrated experimental paradigm. Such an endeavour calls for close collaboration between specialists from a number of mentioned fields in the short term, as knowledge from a diverse set of fields will be called upon in such a process of integration. The proposed experimental paradigm for future research on driver aggression can be further illuminated from the perspective of neuroscience, based on what is known about brain imaging, neural models, depression, and fear. From literature, activity in response to emotional stimuli in a region of the brain called the amygdala, tracked by imaging techniques down to millisecond accuracy, is proposed to hold the key in solving the pressing question, relating to which environmental stimuli serve to instigate aggression. The availability of non-contact video cameras to tract driver's eye movements allows researchers to examine a driver's visual search patterns, extract which part of the driving scene is projected onto the driver's retinas, and correlate these environmental stimuli to brain activation patterns from imaging results (in real-time). Together with subsequent neural network simulations, the understanding brain mechanisms underlying processing of emotional information will be important to understand the phenomenology of aggression. It will also have implications for treatment of aggression and road rage, providing a mechanism behind which the action of therapies can be explained. More information from literature with respect to the set-up and implementation of such an experiment is given in the subsequent sections of this chapter.

In terms of the notion of a model, any kind of scientific statement, concept, law, or any description of a phenomenon is a model which tries to reflect a phenomenon of the external world (Cilliers, 2001). Thus, in short, the activation of the amygdala in the face of emotional stimuli in the traffic environment can be seen as a *phenomenological* model, hypothesised from the basis of extensive medical results referred to in this chapter and Appendix B. Furthermore, in terms of a *future* neural network (connectionist) model of aggression, the appropriate neural network to simulate *observed* stimuli-memory-behaviour relationships (from brain imaging) is both based on the cytoarchitectonic and modular characteristics known to be functionally involved. Temporally accurate imaging explicitly confirms the modular structure and the exchange of information amongst the various parts of the brain. It is not just the amount of detail (at both levels: cellular and network) which determines the observed effects, but also which details. This is in line with the claim for the need of specialised knowledge from neuroscience for models of both neuron functioning and the intra/inter-connection of neurons amongst different brain areas, in order to build a required neural network.

In contrast, the use of just any neural network (like ART, or multi-layer feed-forward networks, or Kohonen maps), selected solely on the grounds of a sensitivity analysis of how well it simulates the stimuli-memory-behaviour relationships, exhibits the same kind of doomed behaviouristic tendency as previous psychological or AI modelling attempts in traffic engineering. Such an effort will typically come from a traffic engineer who disregards vital and available knowledge about brain-behaviour relationships from another field; already applied in other human factors' fields for a considerable time. And so, in terms of a better understanding, nothing is gained.

4.2 State-of-the-Art Technologies for Experimentation

4.2.1 Traffic engineering

Given the diverse circumstances leading to motor vehicle crashes and the associated problem areas and issues, effective collision avoidance countermeasures can best be realised through comprehensive knowledge and understanding of both the events leading to crashes and the contributing driver, vehicle, roadway, and environmental factors. Likewise, with increasingly complex technologies being incorporated into vehicles, such as navigation systems, driver information systems, and wireless communications, there has been an associated increase in the demands placed on the driver and, as a consequence, a potential for increased risk of a crash. In an effort to enhance the capability to study wide-ranging problems and issues associated with the design and implementation of both crash avoidance systems and in-vehicle systems of convenience, a variety of analytical and hardware-based tools have been developed (Barickman and Goodman, 1999). These tools allow the assessment of driver performance and behaviour under a variety of circumstances and conditions in settings that either approximate the real world or are in fact the real world.

An associated problem that has become increasingly apparent in the development of models of driver behaviour over the last few years is the absence of reliable data with which simulated processes, such as car following, may be compared (Brackstone et al., 1999). Obtaining such data, and the associated increase in model validity that this would allow, is clearly becoming of greater importance since a reliable baseline is required against which improvements in traffic flow and safety produced by many advanced transport telematics systems can be judged. Variations in behaviour between drivers and differences in acceleration and deceleration performance of vehicles result in perturbations in traffic flow, which in turn increase accident risk and reduce capacity. Measurement of such behaviour can help in the understanding of the processes involved and the identification of remedial measures, for instance, driver training or advanced transport telematics, and a database of such knowledge could be used for direct analysis or as input to a microscopic simulation model.

Figure 4.1 Example of a laboratory-based driving simulator

In the past, behavioural databases have almost all been collected at discrete spatial and temporal points and on a macroscopic level, for example, speed-headway distributions and relationships extracted from measurements from overbridges (Brackstone et al., 1999). Several novel approaches have also been devised in an attempt to collect information on dynamic, continuous relationships affecting the driving process, for example, collecting data from a bank of video cameras situated along the roadside (Brackstone and McDonald, 1995) or from a helicopter. However, these in turn have met with severe practical problems, such as camera vibration, pixelisation measurement error, driver awareness, and, not least, the logistical difficulties in setting up such surveillance methods and analysing the data.

The alternative to on-road data collection is the use of laboratory-based simulators in which the driver is placed in a fully controlled virtual environment where his/her reactions to external stimuli can be accurately measured in a systematic manner over as long a period as desired (see Figure 4.1). However, the main drawback is the uncertainty about whether the measured driver responses reflect those that would occur in the real world. Regardless of its complexity, the simulator will always be unable to present the rich sensory patterns that occur in real driving, and if an error should be made, it will have little direct consequence on the driver. Nevertheless, such simulators have a significant role to play in research, particularly in the assessment of the effects of alcohol and drugs on driver performance and other factors that would be unsafe to test in a real vehicle surrounded by traffic (Linfield and Dunne, 1988).

Another alternative method of gaining information on behaviour, however, is the use of an instrumented vehicle, which is driven in the traffic stream as a platform from which to observe the behaviour of a test driver or adjacent drivers. This approach is realistic, accurate and relatively inexpensive (compared with simulators) and may be the only method that can produce a sufficient quality and quantity of data to allow the continued development and validation of simulation models (Brackstone and McDonald, 1996).

Significant advances in computational and sensor technology have resulted in capabilities that for the first time allow the evaluation of drivers and systems under truly naturalistic, in situ driving conditions (Barickman and Goodman, 1999). The need for such a capability is obvious given the frequent criticism of research in which the circumstances of data collection are questionable on the basis of realism and the highly controlled settings that are frequently used in such research. Furthermore, the need for field and operational testing of new in-vehicle technologies from the standpoint of effectiveness and safety often demands as realistic a setting as possible. With these requirements in mind, the US National Highway Traffic Safety Administration (NHTSA), for example, has developed a family of vehicle instrumentation systems which allow a wide range of on-the-road testing and evaluation of both conventional technologies (for example, mirror systems) and advanced technologies (for example, rear-end crash avoidance systems, and navigation systems). These systems are portable in that they can be installed in virtually any vehicle. This feature provides desirable versatility and allows research to be carried out on a variety of test beds with a minimal investment in instrumentation. Other equally important features of these systems include the inconspicuous and unobtrusive installation of instrumentation and sensors, use of off-the-shelf technology, long-term data collection potential, extensive upgrade flexibility, and relatively low cost.

Naturalistic data are viewed as falling into three categories:

a) *Baseline data*: Data that would represent the distribution of performance and behaviour of interest, characteristic of a given population of drivers.

b) *Focused data*: Data that would be directed at evaluating a specific aspect, system, or device from the standpoint of its influence on driver behaviour and performance.

c) *Near-miss and incident data*: Data that would focus on the occurrence of near misses and incidents that occur during driving, including antecedent events.

In each of these areas, data collection is associated with its own characteristic set of requirements and constraints for an acquisition system. In the case of baseline data, a system should be capable of long-term acquisition of sampled acquisition under a given set of constraints (for example, speed > 100km/h, turn-signal activation). For focused data collection, the activation or use of the technology of interest (for example, cellular telephone, automatic braking system) as well as antecedent conditions would be required, whereas for near-miss and incident data collection, appropriate triggering criteria (for example, rapid steering rate, hard braking) would be necessary along with antecedent information. The availability of these capabilities provides an invaluable tool for addressing a host of vital design and safety issues associated with both conventional and advanced technologies, and provides an excellent mechanism for validating laboratory-based simulators. It should be noted that because of the very nature of naturalistic data collection and the use of drivers' own vehicles operated under normal, realistic, driving conditions, there is an opportunity to also study more visible contemporary issues, such as intoxicated drivers and aggressive drivers in settings that would otherwise not be possible.

Sensor suite

A vehicle instrumentation system can be composed of a diverse variety of sensors in order to allow collection of a variety of parameters and their derivative measures. The system is generally installed in a subject's vehicle with the following list of basic core parameters:

a) Global positioning system (GPS) – latitude, longitude, speed, heading angle
b) Throttle position
c) Lateral lane position
d) Headway distance
e) Vehicle speed
f) Brake application
g) Lateral acceleration
h) Longitudinal acceleration
i) Vertical acceleration
j) Yaw rate

k) Hand wheel angle
l) Turn-signal activation.

Other parameters and associated measures can be modified or added as needed to meet specific testing requirements. Some examples that have been previously implemented include (Barickman and Goodman, 1999):

a) Brake pedal force
b) Brake line pressure
c) Head position measurement
d) Variety of headway sensors (for example, radar and infrared (IR) based)
e) Audio channels.

Throughout the 1970s and 1980s, work on dynamic data collection was extended to allow the collection of a greater range of pre-dominantly driver-based variables, such as heart rate, electro-dermal response, and electro-myographic measures of muscle tension in order to obtain a physiological measure of driver response to situational stimuli (Helander, 1975).

Another area of interest is in examining the driver's visual search pattern by using records of the driver's eye movements (see Figure 4.2). Until recently, the best way to undertake such an analysis was to use an 'eye mark' camera mounted on a helmet worn by the driver, though because of their bulk these were generally only applied in simulator experiments. Recent developments have now resulted in the availability of non-contact (dashboard-mounted) units, mainly in use by vehicle manufacturers (Brackstone et al., 1999).

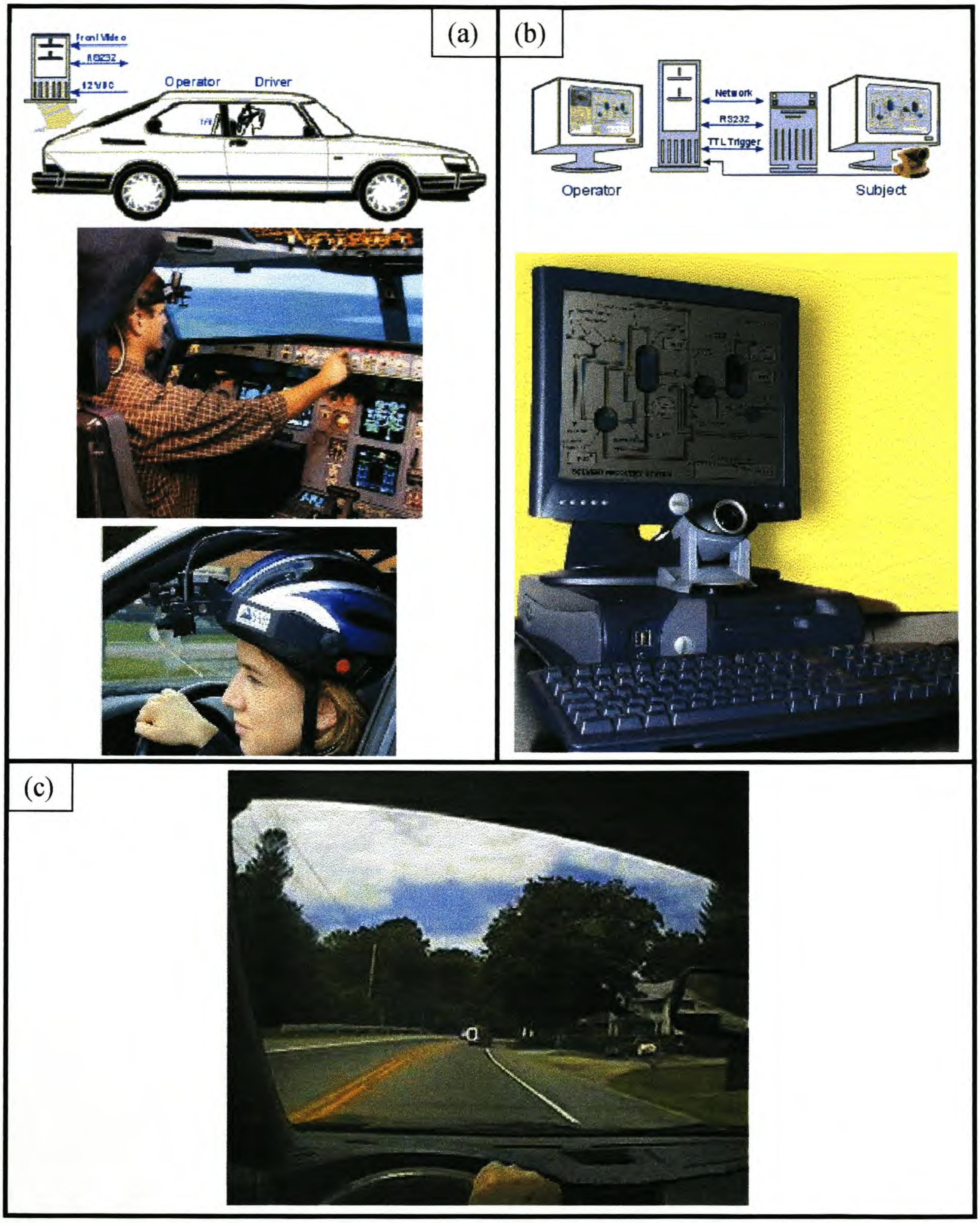

Figure 4.2 Application of eye tracking systems: (a) Head mounted interface, (b) Remote interface (for example, dashboard mounted), (c) Sample image of a subject's field-of-view captured by a head-mounted video camera. The computed gaze position (white circle) is overlaid on the environment image and visualised in real-time (SensoMotoric Instruments)

Data Pre- and Post-triggering

On most occasions, the onset and evolution of an event are not the only or primary data of interest. Therefore, instrumentation systems have the capability to pre-trigger data collection or, in other words, record antecedent data which define the conditions and actions preceding the event itself. Systems are also capable of post-triggering, which enables the system to collect data for some specified amount of time after an event has occurred. For example, an experimenter could define the triggering point of a data collection event as a warning level from a collision avoidance sensor. When the warning is activated, the preceding say 30 s of data leading up to the event would be stored to a file along with the event data and, if desired, data for say a 45 s period following the event. This approach to data collection allows for more efficient data reduction since it eliminates the need to sort through large quantities of data collected. It is also ideal for collecting near-miss and incident data as well as more focused technology-oriented data (for example, activation of a cell phone). Systems can also be configured to collect data defining multiple events using the pre- and post-triggering scheme. These configurations can easily be modified to allow experimenters to look at a variety of questions while only collecting data for a single experimental series (Barickman and Goodman, 1999).

Conclusions

A vehicle instrumentation system is an economical and versatile tool to support the data collection needs for research in a wide variety of transportation fields. Such a system is unique in that it can actually be installed into a subject's personal vehicle, be inconspicuous to other drivers, and be unobtrusive to the driver. System features, such as extended video data collection, event triggering, and the system's ability to pre-trigger data collection, allow researchers the flexibility to collect operational field data over long time periods without intervention. The ability to collect truly naturalistic data over extended periods of time is viewed as an important capability for supporting both human factors and vehicle engineering research covering conventional technologies, advanced technologies, as well as high-visibility driver behaviour, such as aggressiveness and intoxication.

4.2.2 Neuroscience

Neuroscience has undergone explosive growth. New brain-imaging technologies have allowed researchers to address questions which were in the realm of aimless speculation two decades ago.

The manner in which the brain computes in various tasks is being probed at a deep level by these brain-imaging techniques, with an increasing appreciation of the different networks being used to solve these tasks. There is simultaneously developing a neural modelling technology, which attempts to explain the underlying computations being performed by this set of networks. Further, better computers have contributed to improved, more detailed models of neural function. It is becoming increasingly possible to link perception, attention, memory, and other aspects of cognition to neurobiology – which allows the fruits of modern neuroscience to bear on the nature of higher mental function. The study of cognition has moved firmly into the domain of biological science (Squire and Kosslyn, 1998).

For example, recent efforts to integrate psychometric and neurobiological data about personality have stimulated diverse interdisciplinary applications. The dissociation of major brain systems linked to procedural and propositional memory and learning has clarified the clinical distinction between two components of personality: temperament and character. For example, temperament can be defined in terms of individual differences in percept-based habits and skills (related to procedural memory and learning), which are regulated by the amygdala, hypothalamus, striatum, and other parts of the limbic system. In contrast, character can be defined in terms of individual differences in concept-based goals and values (related to propositional memory and learning), which are encoded by the hippocampal formation and neocortex. Recent descriptive, developmental, genetic, and neurobehavioural studies indicate that at least four dimensions of temperament (harm-avoidance, novelty-seeking, reward-dependence, and persistence) and three dimensions of character (self-directedness, cooperativeness, and self-transcendence) can be uniquely described and functionally dissociated (Cloninger, 1994).

Brain-imaging technologies

Perception, action, cognition and emotion can now be mapped in the brain by a growing family of techniques. Positron emission tomography (PET), functional magnetic resonance imaging (fMRI), event-related electrical potentials (ERP), event-related magnetic fields (ERF) and other non-invasive imaging techniques are rapidly evolving and providing an increasingly rich literature on the functional organisation of the human brain. Spatially, temporally, physiologically and cognitively accurate computational models of the neural systems of human behaviour are the ultimate objective of functional brain mapping.

PET and fMRI machines investigate the underlying neural activity in the brain indirectly, the first by measuring the two photons emitted in the positron annihilation process occurring during the radioactive decay of a suitable radio-nuclide, such as $H_2\,^{15}O$ injected into a subject at the start of an experiment; the second from the uneven distribution of nuclear spins (effectively that of the proton) when a subject is in a strong magnetic field (usually of 1.5 T, although a 12 T machine is being built especially for human brain imaging studies) (Taylor, 1999). The PET measurement allows determination of regions of largest blood flow, corresponding to the largest 2-photon count. The fMRI measurement is termed that of blood oxygen level dependent (BOLD). This signal stems from the observation that during changes in neuronal activity there are local changes in the amount of oxygen in tissue, which alters the amount of oxygen carried by haemoglobin, thereby disturbing the local polarisibility. In this system, a giant magnet surrounds the subject's head (Figure 4.3). Changes in the direction of the magnetic field induce hydrogen atoms in the brain to emit radio signals. Much excitement surrounds the newer technique of fMRI in that no radioactive materials are needed and produces images at a higher resolution than PET. Since the method is non-invasive, researchers can do hundreds of scans on the same person and obtain very detailed information about a particular brain's activity, as well as its structure.

Figure 4.3 A normal volunteer prepares for an fMRI study of face recognition. She will have to match one of the faces at the bottom of the display with the face at the top. The researcher adjusts the mirror which will allow her to see the display from inside the magnet. The volunteer's brain is particularly active in an area of her right hemisphere called the fusiform gyrus (arrow) as she matches the faces. This 'slice' of her brain is seen as through looking through her face (National Institute of Mental Health, Maryland)

The sensitivity of the two types of machines is not comparable. Spatially they have a few millimetres accuracy across the whole brain. However, temporally they are far less effective. PET measurements need to be summed over about 60-80 s, limiting the temporal accuracy considerably, while fMRI is far more sensitive to time, with differences in the time of activation of various regions being measurable down to a second by the 'single event' measurement approach. This has already produced the discovery of startling dissociations in the time domain between posterior and anterior cortical sites in working memory tasks (Ungerleider et al., 1998).

Many cognitive studies have been performed using PET; there are now as many using fMRI, some duplicating the PET measurements. These results show very clear localisation of function and the involvement of networks of cortical and subcortical sites in normal functioning of the brain during the solution of tasks. At the same time there has been considerable improvement in the understanding of brain activity in various mental diseases, such as schizophrenia, Alzheimer's and Parkinson's diseases. There have also been studies of patients with brain damage, to discover how the perturbed brain can still solve tasks, albeit slowly and inefficiently in many cases (Taylor, 1999).

The magnetic field around the head, due to neural activity, although very low, is measurable by sensitive devices, such as superconducting quantum interference devices (SQUIDs). Starting from single coils to measure the magnetic field at a very coarse level, magnetoencephalography (MEG) measurements are now being made with sophisticated whole-head devices using 148 or even 250 measuring coils. Such systems lead to ever greater spatial sensitivity, although they have a decided number of problems before they can be fully exploited. In particular, it is first necessary to solve the inverse problem, that of uncovering the underlying current sources producing the magnetic field. This is non-trivial, and has caused MEG not to be so far advanced in brain imaging as PET and fMRI systems.

However, the situation is now changing. There is good reason to bring MEG up to the same standard of data read-out simplicity as PET and fMRI as, although it does not have the same spatial sensitivity as the other two, it has far better temporal sensitivity – down to a millisecond. Messages from the senses travel so swiftly through the brain that PET and fMRI cannot keep up. Thus, MEG fills in the temporal gap on the knowledge gained by PET and fMRI. This is also done with electroencephalography (EEG) (Figure 4.4), which is being consistently used by a number of groups in partnership with PET and fMRI so as to determine the detailed time course of activation of known sites already implicated in a task by other devices (Taylor, 1999).

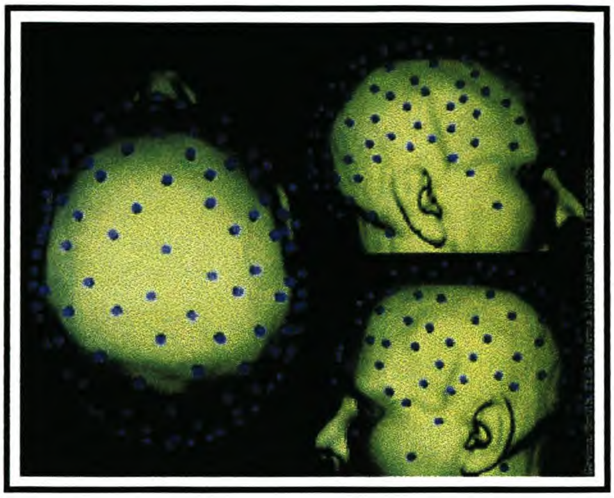

Figure 4.4 In this version of EEG, the positions of 124 recording electrodes (attached to a soft helmet) are carefully plotted on an MRI model of the head (EEG Systems Laboratory, California)

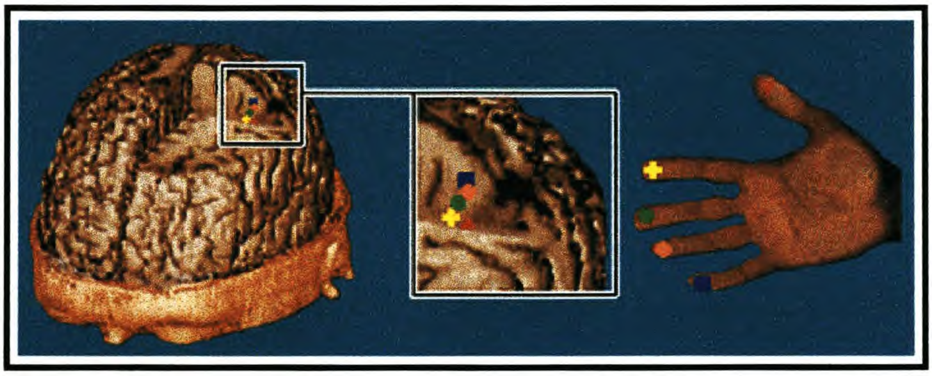

Figure 4.5 Each of the colour-coded areas in this combined MRI/MEG image of the brain responds to the touch of a different finger of the right hand (Llinás, NAS)

This next generation of imaging technology, based on simultaneous measurements of fMRI in various combinations with MEG and EEG, will help researchers examine how various parts of the brain exchange information. One of the first experiments in which fMRI was used jointly with MEG produced a three-dimensional map of the areas of the brain that are activated by touching the five fingers of one hand. A New York University research team headed by Llinás found this map to be distorted in the brain of a patient who had two webbed fingers since birth. A few weeks after the man's fingers were separated by surgery, however, parts of his brain reorganised and the map became almost normal (Figure 4.5).

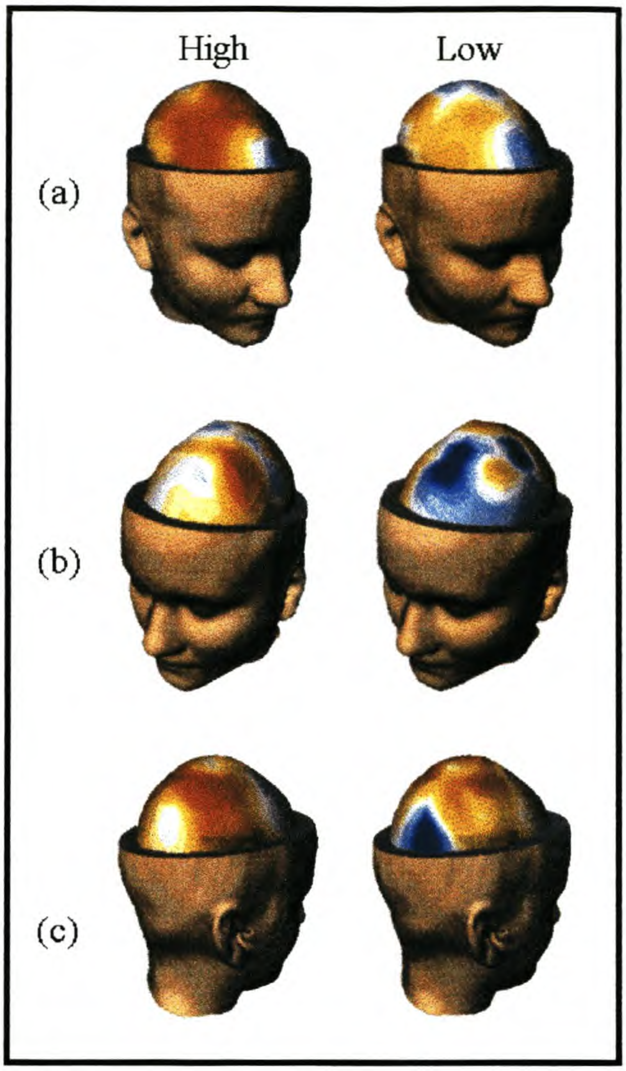

Figure 4.6 The images are based on data from 124 recording electrodes positioned in a soft helmet that covered the woman's head. The scientists used an MRI-derived model of her head to correct for any distortions in electrical transmission that might be caused by variations in the thickness of her skull. The resulting images clearly show that various areas of the woman's brain are activated in turn. However, these images are limited to the brain's surface (EEG Systems Laboratory, California)

In another example, depicted in Figure 4.6, the rapidly shifting patterns of activity in the images reflect what goes on in the brain of a woman who is looking at a letter on a screen during a test at the EEG Systems Laboratory, California. The woman's task is to decide whether the letter is located in the same place as a letter she has seen before. In the 'low load' test she compares the new letter's location to a previous one. In the 'high load' test she compares the new location to three previous ones. The brighter colours reflect a higher degree of brain activation. A strong electrical signal sweeps across the frontal cortex of her right hemisphere 320 milliseconds after a new letter has appeared on the screen, as she compares the letter's location to three locations that she has seen before (Figure 4.6(a)). The same areas of her brain are activated, but less intensively, in the second image, as she compares a new letter's location to only one location that she has seen before. Only 140 milliseconds later (Figure 4.6(b)), a different set of electrical signals is recorded from the volunteer's brain, as recreated in these images. This time the frontal cortex of her left hemisphere is activated as she enters the location of the new letter into her working memory. After the screen goes blank (Figure 4.6(c)), the volunteer rehearses the new memory. This activity produces yet another electrical signal over her right hemisphere. The signals are more intense in the high-load (left) than in the low-load (right) condition.

Output states

Based on the understanding of the functioning of the brain systems for vision, the concept of *output states* in the brain can be put in perspective. Vision is the most extensively studied of the senses, and, in humans, the most valuable. A much simplified schematic diagram of the visual pathway is shown in Figure 4.7.

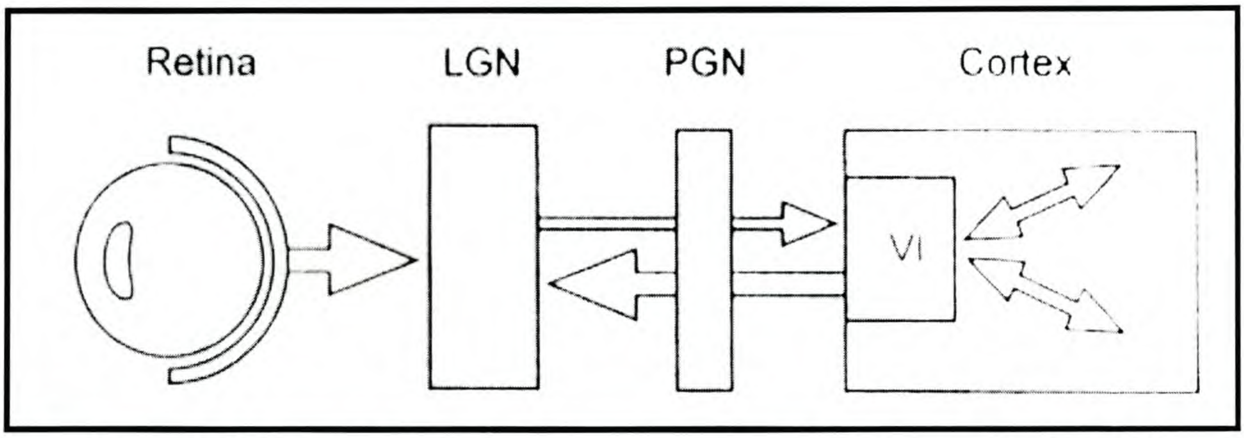

Figure 4.7 Schematic of visual pathways from retina to visual cortex (Harth, 1997)

Visual information gathered by the retina is first conveyed to neurons in the lateral geniculate nucleus (LGN), a structure in the thalamus. From there about a million neural fibres go to a region in the cortex called V1, the first cortical area devoted to vision. A prominent feature – but one rarely discussed by physiologists – is the fact that perhaps 10 times as many fibres descend from V1 and send information back to the LGN. From V1 the visual information travels along several parallel pathways to centres called V2, V3, V4, and many others. Some 30 different visual centres have been identified in monkey cerebral cortex. Again, practically all connections between different cortical centres are reciprocal.

The ubiquity of such loops of connectivity in the central nervous system blurs the distinction between higher and lower cortical centres. There is no strict hierarchy of sensory processing. The 'higher' centres receive information from the 'lower' centres, but these sources are modified, augmented, and censored by the 'higher' centres. The prominence of these return pathways, especially the massive fibre bundle from V1 to LGN, has been one of the great puzzles of cerebral architecture. The cortex is clearly more bent on introspection and confabulation than on forming an unbiased view of the outside world. Mental processes are therefore appropriately called reflective, and concomitant neural activity is cyclic, self-referent. What distinguishes the thinking brain from computers, and from most artificial neural networks, is the fact that in thought processes there are no final, or *output states* (Harth, 1997).

4.3 Setup and Application of an Integrated Experimental Platform

4.3.1 Integration – a next step

The problem of how the mind relates to the brain stands as one of the greatest challenges today. The materialistic worldview and pragmatic approach to social problems are both being transformed by discoveries of how human experience and culture arise in cerebral activity. Even so, this process, spearheaded by neuroscience, has seen the important and contentious issue of driver behaviour somehow been left behind. From the author's extensive literature study, to explore the multi-faceted research on drivers' behaviour, it can be concluded that gross disregard of the neural underpinnings of such behaviour tied to a behaviouristic approach is endemic to the field. In general, a stalemate exists with numerous disputed qualitative psychological models (Michon, 1989).

Psychological research has been extremely valuable, but an approach where cognition and emotion are studied as brain functions is far more powerful. Additionally, studying the way cognition and emotion work in the brain can help to choose between alternative psychological hypotheses – amongst all possible solutions to the question of how cognitions and emotions might work, the only relevant one (in understanding human behaviour) is the solution which was put into the brain with creation (LeDoux, 1998). Being a human driver incorporates a broad complement of interrelated brain systems to perform driving tasks (psychological functions) at hand, such as lane keeping, speed choice, risk perception, and obstacle avoidance. The proper level of analysis of such a psychological function is the level at which that function is represented in the brain.

However, there are still those researchers maintaining that neurophysiological plausibility is irrelevant to psychological theorising, and that the gap between knowledge of what brain structure is and how it produces behaviour is so wide that any endeavour to make psychological theories neuronally plausible is at best unhelpful, and at worst positively misleading. These views, together with the fond hopes of opportunistic minimalists (like 'strong AI') (Dennett, 2001) have been dashed – they had hoped they could leave out various detail, like functional neuroanatomy and neurochemistry, and they have learned that no, if one leaves out x, or y, or z, one cannot explain how the mind actually works. To understand what humans actually do while exposed to various traffic environments as opposed to what humans are capable of doing, it is of utmost importance to let the fruits of modern neuroscience bear on the nature of driver behaviour models.

Integration process

As discussed in a previous section, state-of-the-art technologies within transportation engineering offer advanced capabilities for data and parameter measurement and extraction from driver behaviour experiments. A rich set of data can currently be obtained in such experiments performed in a simulator or instrumented vehicle, such as video and audio capturing, as well as spatial and temporal characteristics of objects forming part of the driving environment, especially those for the driver. Notwithstanding the diverse variety of data types available from driver behaviour experiments, data mining is essentially based on the underlying behaviouristic models presently applied in transportation engineering. The aim of a traditional model, such as a psychological or AI model, is to describe the performance of the subject, not the way that the performance is achieved. This puts such models in stark contrast to what has been an ongoing revolution in the understanding of how the human brain, given streams of input from a structured world by its sensory receptors, can perform functions and learn novel facts in a humanlike manner by means of a system which computes with simple neuron-like elements, acting in parallel. Thus, the neuroscientific approach is the reverse. In general, it starts with a model which incorporates brain-like processing and sees whether behaviour emerges, which mimics that shown by people.

At the moment, the principal source of information on the global brain in action involves the discipline of functional brain imaging. Together with descriptions of the functions performed by the various brain areas, observed active while human subjects solve various tasks, these experimental paradigms are currently spearheading an attack on the modus operandi of the brain in toto (Taylor, 1999). Thus, in order to align research on driver behaviour so that contemporary neuroscience can bear on the knowledge and understanding of such behaviour, a necessary step would be to incorporate brain-imaging devices into the sensor suite of driver behaviour experiments. Accompanying the implementation of brain imaging, an imperative further step, needed to be taken by driver behaviour modellers, would be to develop neural network simulations which give overall agreement in activations with that observed in brain-imaging experiments. These mentioned steps will contribute towards bringing driver behaviour research on par with the level of advanced knowledge on human behaviour offered in modern neuroscience, and introduce the well-instrumented and closely-monitored experimental platform offered by driver behaviour research into mainstream neuroscientific experimentation.

To illustrate the advances achievable in better understanding and modelling driver behaviour through integration of neuroscientific principles and know-how into driver behaviour experimentation, consider the collection of driver-based variables, such as heart rate and electrodermal response in order to obtain a physiological measure of driver response to situational stimuli. Not only can neuroscience provide an explanation of how the autonomic nervous system (ANS) and hormonal responses (leading to changes in heart rate and sweating) are brought about (see Appendix B for a detailed discussion), but it can also shed light on the rather low utility of monitoring such driver-based variables in isolation. These visceral responses have relatively slow actions, too slow to be the factor determining which emotion the driver experiences at a given moment (LeDoux, 1998). A far more robust methodology currently available for linking up driver response to specific situational stimuli, would incorporate brain imaging and neuroscientific know-how of the specific brain networks been activated sequentially (down to milliseconds) to produce the mentioned visceral responses.

It is also important to note that in preparing driver behaviour experimentation in order to incorporate principles and knowledge from neuroscience, the sensor suite for the collection of driver-based data should be capable, inter alia, to capture the environmental stimuli impinging on the human senses. Everything humans know about their world comes to them through their senses of sight, hearing, smell, taste, and touch. Although scientists recognise that there are several additional kinds of sensations, such as pain, pressure, temperature, joint position, muscle sense, and movement, these are generally included under 'touch'. (The brain areas involved are called the somatosensory areas.) An example of capturing such a stream of input on a sensory receptor involves driver sight or vision. As mentioned in a previous section, recent developments have resulted in the availability of non-contact (dash-board-mounted) video cameras to tract driver's eye movements. These records allow researchers to examine the driver's visual search patterns and to extract which part of the driving scene is projected onto the driver's retinas (in real-time).

Final remarks

To further driver behaviour modelling through the implementation of the envisaged integrated platform for experimentation, collaboration is needed among investigators from the fields of neuroscience, psychology, mathematics, computer science, and engineering. In this process, the use of modern brain-imaging techniques will be invaluable in establishing and applying knowledge in terms of the neural correlates of particular driving subtasks and different driver behaviours. Providing a neurally-inspired computational model of general human behaviour is a challenge for decades to come. Driver behaviour research is an integral element in achieving this quest. Consequently, driver error will be understood better, driver education enhanced, and computer-aided telekinesis for driving realised. Above and beyond, the experimental platform within the driving environment provides proving grounds for models of general human behaviour. However, in doing so, the extent of structural impacts on the brain of each individual, brought about by a lifetime of interaction with the environment, may not be overlooked or disregarded.

4.3.2 Towards the better understanding of an important issue in transportation engineering: aggressive driving

Aggressive driving can be defined in terms of the frustration-aggression model, originally proposed by Dollard et al. (1939). In this context aggressive driving is a syndrome of frustration-driven behaviours, enabled by the driver's environment filled with experiences of stress, anxiety, anger, antagonism, and fear (James, 1997). These behaviours can either take the form of instrumental aggression – that allows the frustrated driver to move ahead at the cost of infringing on other road users' rights (for example, by weaving and running red lights) – or hostile aggression which is directed at the object of frustration (for example, cursing other drivers). Interestingly, Dollard et al. chose to illustrate the frustration-aggression model with the behaviour of a hypothetical college student who is stopped and berated by a police officer (the frustration source) in front of his girlfriend. Once he drove away, the student "grated the gears frequently in shifting, refused to let other cars pass him, and made insulting comments about every policeman who came in sight". This link of aggression to frustration is very important, since it implies that a frustrating situation, behaviour, or event instigates all aggressive behaviours (Shinar, 1998).

While these behaviours may be reflective of individual differences in aggression, it can be argued that the exclusive focus on the characteristics of the aggressive drivers and how to control them is short-sighted. Instead, Shinar (1998) proposes an ergonomic-oriented approach that involve environmental modifications. For greater highway safety, the greatest benefit of embracing the frustration-aggression model is that it provides a systems approach to the problem. As such it can be used to show that aggressive driving can be reduced not only by changing driver behaviour directly (for example, through enforcement) but also through changes in the environment that breeds aggression. Furthermore, efforts that focus exclusively on restraining driver instrumental aggression through enforcement may actually contribute to road (or off-road) rage and displaced aggression. This viewpoint of aggressive behaviour does not negate the existence of individual differences in aggression, but it does highlight the contribution of the environment (in frustrating the drivers' goals) to aggressive behaviour. The role of personality and predisposing tendencies that a driver brings with him/her to the driving environment is illustrated by Retting and Williams'

(1996) finding that red light violators are three times as likely to have previous multiple violations in comparison to non-violators.

Shinar (1998) proposes that over the past few decades drivers have not changed their personality and have not become more aggressive people. Instead, the conditions that elicit aggressive behaviours – especially on the road – have changed, so that the level of frustration is above the 'aggression threshold' for more and more drivers. As an example, consider the role of congestion as a common source of frustration and aggression. In light of this, it is rather unfortunate that the focus of the aggressive driving issue has been almost exclusively on who are the aggressive drivers and what aggressive behaviours they display, rather than on why drivers in general are more aggressive now than before, and what can be done (not necessarily to the drivers) to ameliorate the situation. Given this approach, in order to reduce or eliminate aggressive driving by treating its causes rather than its carriers (especially when driver surveys suggest that aggressive driving characterises the majority of the driving population), researchers need to first identify the sources of the frustration.

Evaluation of existing measures of aggression

From research results it appears that overt behaviours, such as affective (horn honking, vocalisations, and gesturing) and instrumental (acceleration) responses, currently employed in experiments, bring about a number of difficulties as reliable indicators for signalling driver frustration and aggression. For example, consider gender differences in aggression and violent behaviour, which have been studied ad-nausea. In a meta-analysis of 143 studies, which examined gender differences in aggressive behaviour, Hyde (1984) found that while none of the studies showed that women were more aggressive than men, and many studies showed that men are more aggressive, the gender differences explained only 5% of the variance, once other individual characteristics were taken into account. However, the discrepancy between this result and the over-involvement of males in violent crimes is due to the fact that in most psychological studies, the aggressive behaviour being measured does not take into account that women are less likely to exhibit extreme aggression, but, although possibly just as likely to be frustrated, they exhibit aggression in more subtle terms (Shinar, 1998). In driving, aggressive behaviours span a wide range from muttering, through yelling and making obscene gestures, and all the way to violent actions with the car. Furthermore, the horn honk response, used predominantly because the latency, duration, and frequency of a honk can be easily measured and readily elicited as a form of aggression, is also questionable as a measure of aggression (McGarva and Steiner, 2000).

In addition, consistent with knowledge from neuroscience (discussed in a previous section), physiological responses do not correlate reliably with overt aggressive behaviours. Although one expects that drivers who respond more aggressively to provocation (another factor apart from frustration that elicit aggression) will also exhibit heightened physiological responses, McGarva and Steiner (2000) did not observe changes in heart rate and blood pressure to vary as a function of driver aggression. Taken together, the failure to observe the expected reliable relationships amongst aggression, overt behaviours, and visceral arousal raises questions about the soundness of the present experimentation paradigm. Thus, despite efforts to provide a robust definition of aggressive driving, Shinar (1998) believes that there remains a need for a more operational, useful, and commonly agreed-upon definition of aggressive driving. Overt behaviours and physiological responses are just not specific enough.

What present results do show are the strong associations between the environmental conditions under which drivers operate and the level of manifest aggression. The ergonomic approach to problem solving assumes that (a) in a system in which many users behave 'inappropriately', the fault is more likely to be with the system design than with the individual users, and (b) it is more efficient (and more user-friendly) to change bad design than to force people to adapt to it. In his testimony to Congress, Martinez (1997), the NHTSA administrator also noted several examples of how changes in traffic travel patterns reduced traffic violations and crashes. However, some of the mediating factors cannot be that easily manipulated to reduce stress, such as time of day, and geographically and culturally based norms. Other factors – such as congestion producing factors – are costly to affect. Nonetheless, it is critical to consider these factors if aggressive driving is to be reduced (Shinar, 1998).

To summarise, research on aggressive driving to-date demonstrates that a significant amount of aggressive driving can probably be reduced by a careful, user-friendly, and ergonomically oriented design of the driving environment. Also, from an effective public health perspective the way to reduce road aggression should be to control the situations that give rise to it, rather than focus exclusively on driver education and mass media campaigns. However, before these results can be applied, they should be validated extensively. Apart from difficulties with present measures of aggression, much more data are needed on the relationship between environmental stimuli, individual differences and aggressive driving, before action oriented large-scale programs can be justified (Shinar, 1998).

Incorporating neuroscientific know-how

In order to revitalise and advance not only research and the subsequent knowledge-base on driver aggression, but also on all other driver-related issues, the author proposes a shift towards the integrated experimental paradigm, as discussed previously. Such an endeavour calls for close collaboration between specialists from a number of mentioned fields in the short term, as knowledge from a diverse set of fields will be called upon in such a process of integration. This is a premium for worthwhile insights and progress to stem from such a research program. However, the proposed experimental paradigm for future research on driver aggression can be further illuminated from the perspective of neuroscience, based on what is known about brain imaging, depression, and the emotion of fear.

Consider the fact that previous psychological research suggests that depressed individuals engage in prolonged elaborative processing of emotional information (Siegle et al., 2002). Armed with a computational neural network model of emotional information processing and event-related fMRI, Siegle et al. found that activity in response to emotional stimuli in a region of the brain called the amygdala was sustained in depressed individuals, even following subsequent distracting stimuli. Since the amygdala is known to be involved in processing emotion, that is not altogether startling. The difference in sustained amygdala activity to negative and positive words was only moderately related to self-reported rumination (through questionnaires).

Amygdala activity was also inversely related to activity in dorsolateral prefrontal cortex (DLPFC), which is consistent with the idea that depression could involve, in part, decreased inhibition of the amygdala by cortex. This study has a number of potentially important clinical implications. Depressed individuals are frequently observed to have difficulty in life situations not considered to be inherently emotional. Results suggest that a depressed person's experience of an emotional stimulus could persist well beyond that stimulus, and in fact, could persist into the time they are expected to be engaging in other activities, leading to interference with these subsequent activities. Observations also suggest that understanding brain mechanisms underlying sustained processing of emotional information may be important to understand the phenomenology of depression. It can also have implications for treatment of depression, providing a mechanism behind which the action of therapies can be explained. For example, re-engaging inhibition from DLPFC through Wells' (2000) attentional control training can decrease sustained amygdalar activity.

A great deal of evidence suggests that emotional information is processed in parallel by brain systems responsible for identifying emotional aspects of information (the amygdala system) and other brain areas primarily responsible for identifying non-emotional aspects of information (the hippocampal system) (LeDoux, 1998). These systems are highly interconnected and subject to feedback. Ingredients of an emotional feeling needed to turn an emotional reaction into a conscious emotional experience, like depression, fear, or aggression, can be summarised as:

a) A specialised emotion system which receives sensory inputs and produces behavioural, autonomic and hormonal responses.
b) Cortical sensory buffers which hold on to information about the currently present stimuli.
c) A working memory executive (prefrontal cortex) which keeps track of short-term buffers, retrieves information from long-term memory and interprets the contents of the short-term buffers in terms of activated long-term memories.
d) Cortical arousal keeping conscious attention directed towards the emotional situation.

Bodily feedback – somatic and visceral information which returns to the brain during an act of emotional responding.

The fear system is understood as well or better than other emotional systems (LeDoux, 1998) (the author wants to explicitly refer readers to Appendix B.4 for a detailed discussion of the amygdala and emotional behaviour). The fear system is not, strictly speaking, a system that results in the experience of fear. It is a system which detects danger and produces responses which maximise the probability of surviving a dangerous situation in the most beneficial way. In other words, it is a system of defensive behaviour. Interactions between the defence system and consciousness underlie feelings of fear, but the function of the defence system is survival in the face of danger. The discovery of a pathway which could transmit information directly to the amygdala from the thalamus suggested how a conditioned fear stimulus could elicit fear responses without the aid of the cortex. The direct thalamic input to the amygdala simply allows the cortex to be bypassed. The fact that emotional learning can be mediated by pathways which bypass the neocortex is intriguing, for it suggests that emotional responses can occur without the involvement of the higher processing systems of the brain, systems believed to be involved in thinking, reasoning and consciousness.

Neurons in the area of the thalamus which projects to the primary auditory (and visual) cortex are narrowly tuned – they are very particular about what they will respond to. However, cells in the thalamic areas which project to the amygdala respond to a much wider range of stimuli and are said to be broadly tuned. Although the thalamic system cannot make fine distinctions, it has an important advantage over the cortical input pathway to the amygdala in terms of time (Figure 4.8). In a rat, the thalamic pathway is twice as fast. However, because the direct pathway bypasses the cortex, it is unable to benefit from cortical processing. As a result, it can only provide the amygdala with a crude representation of the stimulus. It is thus a quick and dirty processing pathway. The direct pathway allows a person to begin to respond to potentially dangerous stimuli before he/she fully knows what the stimulus is. This can be very useful in dangerous situations. However, its utility requires that the cortical pathway be able to override the direct pathway. It is possible that the direct pathway is responsible for the control of emotional responses unbeknownst to a person. This may occur in all humans some of the time, but may be a predominant mode of functioning in individuals with certain emotional disorders.

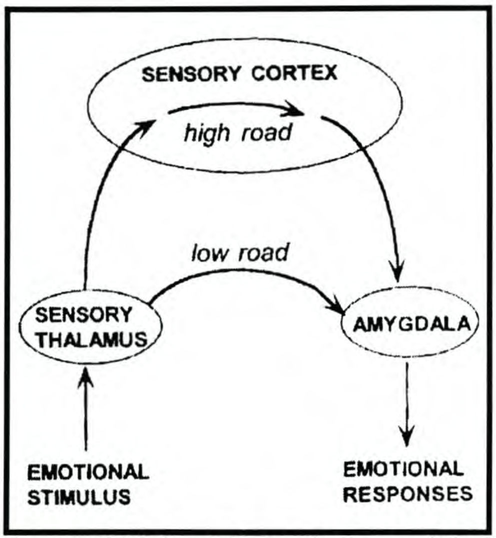

Figure 4.8 The low and high roads to the amygdala (LeDoux, 1998)

The responsibility of the cortex is to prevent the inappropriate response rather than to produce the appropriate one. For example, consider driving along a highway and seeing a number of thin parallel lines running across the surface of the road. The cortex would be needed to distinguish a speed trap from among many other possibilities. However, responding immediately through braking could save the driver a speed fine.

The amygdala is like the hub of a wheel. It receives low-level inputs from sensory-specific regions of the thalamus, higher level information from sensory-specific cortex and still higher level (sensory independent) information about the general situation from the hippocampal formation. Through such connections, the amygdala is able to process the emotional significance of individual stimuli as well as complex situations. The amygdala is, in essence, involved in the appraisal of emotional meaning and where stimuli do their triggering.

To summarise, it is not unreasonable to suggest that by knowing what the different inputs to the amygdala are, and having some idea of what function those areas play in cognition, one can get some reasonable hypotheses about what kinds of cognitive representations can arouse certain emotional responses. By the same token, if it is known how the brain achieves some cognitive function, and it can be determined how the brain regions involved in that function are connected with the amygdala, one can explain in a plausible way how such emotions might be aroused by that kind of cognition. Thus, by knowing which cortical areas project to the amygdala, and knowing the functions in which those areas participate, one can make predictions about how those functions might contribute to emotional responses. Anatomy can, in other words, illuminate psychology, thereby enhancing the understanding of human behaviour.

4.3.3 Summary

State-of-the-art technologies within transportation engineering offer advanced capabilities for data and parameter measurement and extraction from driver behaviour experiments. A rich set of data can currently be obtained in such experiments performed in a simulator or instrumented vehicle, such as video and audio capturing, as well as spatial and temporal characteristics of objects forming part of the driving environment, especially those for the driver. In terms of neuroscience, the principal source of information on the global brain in action involves the discipline of functional brain imaging. Together with descriptions of the functions performed by the various brain areas, observed *active* while human subjects solve various tasks, these experimental paradigms are currently spearheading an attack on the functioning of the whole brain.

To further driver behaviour research, so that contemporary neuroscience can bear on the knowledge and understanding of such behaviour, a necessary step would be to incorporate brain-imaging devices into the sensor suite of driver behaviour experiments. To complement this add-on, the sensor suite for the collection of driver-based data should also be capable of capturing the environmental stimuli impinging on the human senses, such as vision, hearing, and touch. Accompanying the implementation of brain imaging, an imperative further step, needed to be taken by driver behaviour modellers, would be to develop neural network simulations which give overall agreement in *activations* with that observed in brain-imaging experiments. Extensive neuroscientific research has linked the sequences of activation of different brain areas for a host of various tasks, which enable scientists to understand and impact on driver behaviour in terms of the underlying neural processes.

The implementation of the envisaged integrated platform for experimentation calls for collaboration among investigators from the fields of neuroscience, psychology, mathematics, computer science, and engineering. Providing a neurally-inspired computational model of general human behaviour is a challenge for decades to come. Driver behaviour research is an integral element in achieving this quest. Consequently, driver error will be understood better, driver education enhanced, and computer-aided telekinesis for driving realised. Above and beyond, the well-instrumented and closely-monitored experimental platform within the driving environment provides proving grounds for models of general human behaviour.

To conclude, the proposed experimental paradigm for future research on driver aggression, as depicted in Figure 4.9, is based on a multi-disciplinary effort, and on what is known about brain imaging, neural models, depression, and fear. From literature, activity in response to emotional stimuli in a region of the brain called the amygdala, tracked by imaging techniques down to millisecond accuracy, is proposed to hold the key to understand better which environmental stimuli serve to instigate aggression. The availability of non-contact video cameras to tract driver's eye movements (in traffic simulators or instrumented vehicles) allows researchers to examine a driver's visual search patterns, extract which part of the driving scene is projected onto the driver's retinas, and correlate these environmental stimuli to brain activation patterns from imaging results (in real-time). Together with subsequent neural network simulations, the understanding brain mechanisms underlying processing of emotional information will be important to understand the phenomenology of aggression and road rage.

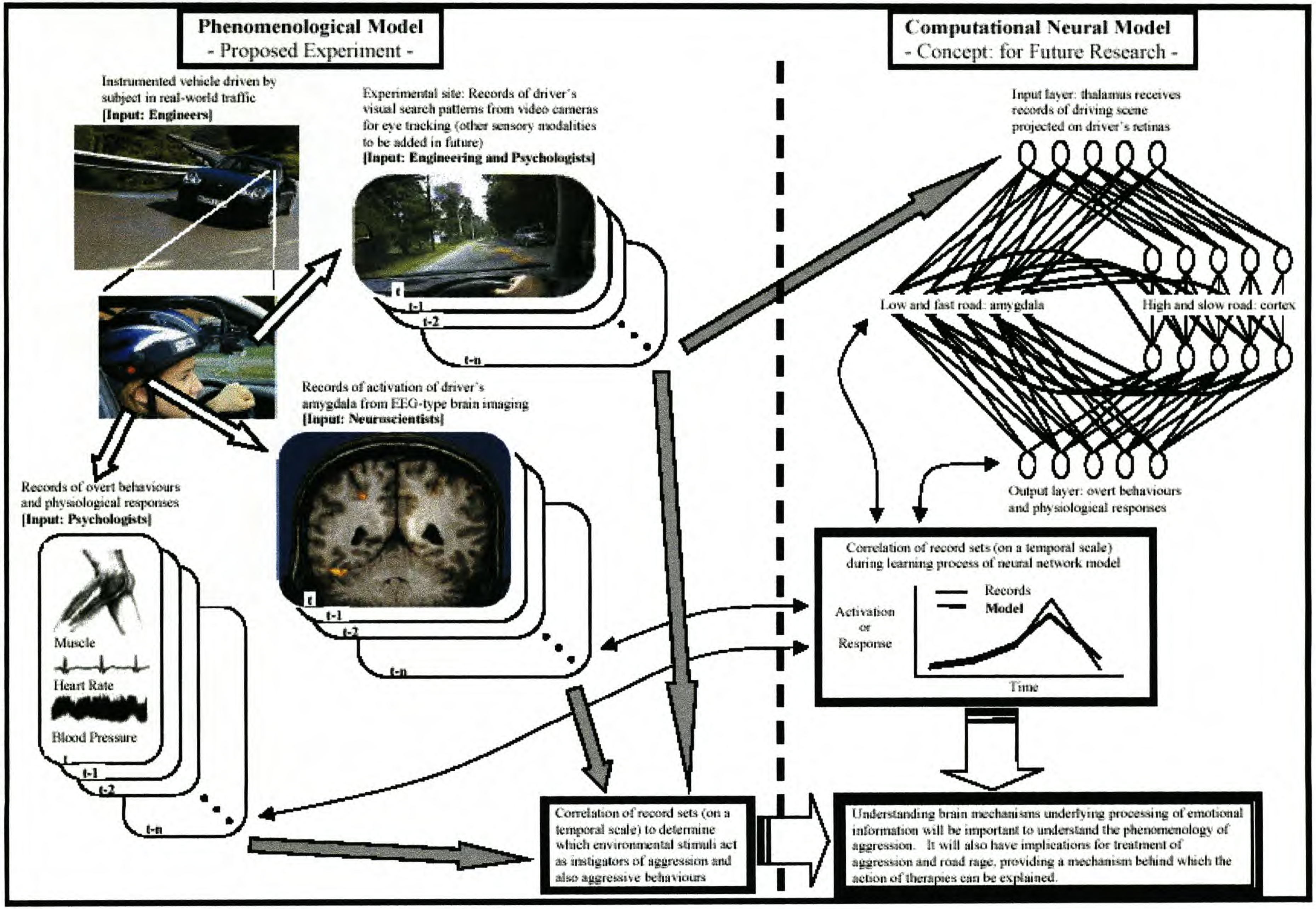

Figure 4.9 Flow diagram of proposed experimental paradigm for aggression investigations

CHAPTER 5

CONCLUDING REMARKS – FINDINGS AND PROPOSITIONS

5.1 Summary of Research Work

The objectives of the research reported in this dissertation have been fulfilled:

a) From an extensive literature study on the state-of-the-art of driver behaviour modelling, the effect of behaviourism on the current stalemate and lack of new ideas in the field is apparent.

b) The power of rooting observed driver behaviour on neuroscientific knowledge, to understand better how such behaviour arises from the neural underpinnings of human brain functioning, has been demonstrated, supported by case studies from literature.

c) Ways and means have been proposed to combine knowledge from neuroscience, psychology, computer science, and engineering to lay the platform from which to study and model driver behaviour holistically in future. Specifically, the author has put forward an experimental paradigm for future research on driver aggression based on a multi-disciplinary effort, and on what is known about brain imaging and activation, neural models, depression, and fear.

To summarise, future transportation systems will integrate many sophisticated technologies, including, for example, congestion prediction, dynamic routing, incident detection algorithms, and automated emergency response generation. Systems of this complexity may lead to a large number of diverse and complex interactions between the different components of the system. Computer simulations which link the traffic control logic with a lane level traffic model which accurately represents the movements of vehicles through the network can provide an understanding of these interactions and motivate possible improvements to the design of the system. The feedback or interaction between the control system and the traffic flow system is a key issue of an evaluation. This requires that the simulation incorporate models for driver response. Only microscopic simulation models provide the required level of detail and only a model which provides the capability of modelling the dynamic interaction between the traffic management system and the traffic flow on the network is appropriate for evaluation of these systems.

Although efficiency and quality of mobility are important interests, especially for future intelligent technologies, safety remains the predominant preoccupation of traffic engineering. It should be evident that while current and future technologies have the potential to improve traffic safety, they also have the potential to adversely affect it. Ultimately, the effect on safety depends on the specific technologies that are invoked and the manner in which they are incorporated within the vehicle as well as within the larger road transportation system. Current automotive developments can be characterised as technology-centred solutions rather than user-centred solutions. Greater effort must be directed at understanding and accommodating the human element in the road transportation system in order that transportation objectives can be achieved. There is a need to expand the scope of traditional human factors to understand human interactions with other elements of the transportation system. Designers need models of the human information-processing system that will predict driver decision-making, situational awareness and strategies for negotiating in traffic. Such models, supported by much greater computing power, will revolutionise traffic analysis.

Transportation lies between a social system and a physical system – it goes beyond physics to a human scale. On the physical side are the striking variety and number of vehicles and road systems, each contributing its own peculiarities, as well as the weather and other environmental factors. The social, behavioural side encompasses not only the individual preferences and second-by-second reactions of drivers but also actions taken by the rest of society. To understand the forces acting on traffic flow, transportation planners have to analyse the many possible outcomes from this complex network of decisions.

It seems that there has been a trend in the past to consider physics as reality and the psychological response as a deviation from that reality. However, independent and dependent variables are actually being mixed up, a mistake that is only now being exposed. Thus, deriving equations from physical descriptions of motion and subsequently trying to fit these to data derived from behavioural responses, both literally and figuratively, puts the cart before the horse. It is a historical result of the fact that most traffic modellers are trained in physics and grounded in engineering. As a result, such models have proved largely disappointing. Modellers also frame the question of behaviour around the idea of optimal performance. The reality is that the pluralistic motivations of different drivers and the dominance of satisficing behaviour in driving mean that such models are unlikely to render the 'grail' of a simple formula. Differing contextual factors from the driving environment add layers of complexity to modelling as such factors are introduced.

These efforts can rapidly devolve to curve-fitting exercises in which additional degrees of freedom are added to formulations, as more contextual elements are included. What such models eventually represent, in driving terms, only their advocates can explain. Generally, there is no spark of intelligence and no learning; there is only data-driven information processing. If the outcome of a programme run will be at all surprising, it is simply because of the complexity of the computation.

A related problem in driver behaviour modelling revolves around the fact that rules which describe externally observable behaviour and rules which determine the functional relations which generate such behaviour tend to be confused or combined indiscriminately. Using a rule which describes observable behaviour as a shorthand expression for internal information processing brings with it the risk of infesting the model with pernicious homunculi or vicious circles – technically speaking one is putting the explanandum in the explanans. Artificial Intelligence models, such as rule-based systems, may seem to conform to the principle of making a clear distinction between these two types of rules. However, ruled-based models, such as Soar, are built on the assumption of rational reasoning and learning from rules of logic, which, among numerous other objections, is not supported by literature as being characteristic of human behaviour, especially not emotionally-laden decisions. On the other hand, psychological (motivational) models, such as the Theory of Risk Homeostasis and Fuller's risk avoidance model, have been criticised for being qualitative in nature, applicable only to single-instance situations, and lacking specificity regarding their internal mechanisms, which precludes validation.

Although these models may, for example, be employed as the robot controllers of the computer-driven vehicles on the displayed driving scenery of a traffic simulator experiment, traffic engineers and psychologists are really in need of *quantitative* models of *human* behaviour to explain what humans actually do while exposed to various traffic environments, as opposed to what humans are capable of doing.

Little has been done to determine what makes road users speed, drive while drunk, overtake, or yield at crossroads. While the risk of accident involvement may represent a motivational factor, there are clearly others which play equally important roles. If traffic researchers are to be successful in modifying driver behaviour through education, publicity or enforcement activities, the identification of the underlying mechanisms is of primary importance. Unless models of driver behaviour are developed which take account of these mechanisms, modelling will not be able to accurately predict behaviour, and will offer very little guidance for developing measures aimed at influencing the behaviour involved. Unlike the researcher and the policy maker, road users have other things to worry about than accident statistics.

Furthermore, traffic engineering and psychology carves driver behaviour up into functional pieces, such as risk perception, sensation seeking, and road rage – just as psychology carves the mind up into pieces, such as perception, memory, and emotion. These functional pieces are useful for organising information into general areas of research but do not refer to real functions. Psychological research has been extremely valuable and there is *no* denying of the validity and utility of observed driver behaviour documented in literature. However, an approach where driver behaviour is studied in terms of brain functioning is far more powerful and can help to choose between alternative psychological hypotheses. The proper level of analysis of a psychological function is the level at which that function is represented in the brain. Unless neurobiological plausibility is attended to, the functionalism that driver behaviour can be understood independent of knowledge of how the brain works, will cost the field dearly.

The driving task draws on a considerable number of human capabilities and functions, such as perception (vision, hearing, and touch), attention, memory (encoding and retrieval of procedural and declarative memory), motor control, language, and emotions. Furthermore, expert neural systems, specialised towards performing the mentioned functions, are all interdependent and interacting on various levels while impacting to a greater or lesser degree on the observed behaviours during the course of a drive, such as obstacle avoidance, speed choice, and passing manoeuvres. Therefore, it is important to realise that research on driver behaviour really necessitates studying the central nervous system as a whole. Implementation of a piece-meal set of models of different psychological paradigms seems to do disservice to the efficiency and remarkable unity of the brain in normal action. Furthermore, mental disorders (such as road rage and disregard for traffic laws), like mental order, reflect the workings of the brain.

Hebb put forward the case for basing models of brain functions on what is known about the physiology of the brain, enabling the anatomist, physiologist and neurologist to contribute to psychological theory. Hebb thought that it would help psychological theorising if there is an input from neurophysiology. Regrettably, some researchers maintain that neurophysiological plausibility is irrelevant to psychological theorising and that the gap between knowledge of what brain structure is and how it produces behaviour is too wide. However, others, reacting to the functionalism that the mind can be modelled independent of knowledge of how the brain works, have argued that nature is more ingenious than humans are. Humanity stands to miss all that power and ingenuity unless neurobiological plausibility is attended to. The point is, it has already been done in nature, so why not learn how the human brain actually works?

Fortunately, in the last decade or so there has been an ongoing revolution in the understanding of how the human brain, given streams of input from a structured world by its sensory receptors, can perform functions and learn novel facts in a humanlike manner by means of a system which computes with simple neuron-like elements, acting in parallel. The investigation of what can be achieved by models which perform parallel distributed processing is called connectionism. Since the central principles of connectionist models are derived from current knowledge of computation within the brain, the models are said to be 'neurally inspired'. This puts them in stark contrast to traditional models in psychology or Artificial Intelligence. Traditional models in psychology contain box-and-arrow elements like limited capacity channels, articulatory loops and short-term memory stores. Models in AI contain sets of rules. In general, no attempt is made to relate the operations these elements perform to the way the brain works at a neuronal level. The aim of a traditional model is to describe the performance of the subject, not the way that the performance is achieved. The connectionist approach is the reverse. It starts with a model which incorporates brain-like processing and sees whether behaviour emerges, which mimics that shown by people. Nevertheless, there are some drawbacks to this approach. For example, researchers do not have a complete understanding of the way that information is transmitted between neurons in the brain. The method of passing information from neuron to neuron in connectionist models certainly occurs, at least at a conceptual level. However, in the brain there are other methods of inter-neuronal signalling which are not yet implemented in connectionist models. But, the important point is that completely accurate neural models will be possible in the future.

An appealing aspect of the connectionist approach is that the models of cognitive processes are computational. That is, they actually produce a response to a stimulus. The predictions that such models make about reaction time or error rate or interference can be compared at a quantitative level to the behaviour produced by subjects in experiments. The inability of many traditional models in psychology to do more than make qualitative predictions about the effect of some experimental variable on performance has often made it difficult to choose between them because they make the same qualitative prediction. Connectionist models have given a precise match to data obtained in experiments with human subjects. Connectionist simulations do not just mimic results which are already known, but their predictions have suggested fruitful areas for experimentalists to investigate. Therefore, to mimic human behaviour it would be advantageous to base modelling on a system architecture relating operations such as stimulus processing, learning, memory retrieval, emotions, and motor control to the way the brain functions at neuronal level. Thereby it can be ensured that the 'required' and 'appropriate' intelligence and learning mechanisms are built into the model.

The brain is a *continuously* self-organising measuring device in the world, and of the world. Apart from knowledge of the anatomy (wiring) of the brain, equally important issues in understanding human behaviour (and therefore driver behaviour) are the shaping effects of experience and practice, in association with learning mechanisms and the process of information storage, from birth over the years to adulthood, studied in developmental biology and psychology. People differ in the pattern of their mental abilities because their brains grow in different forms. Some of this diversity of human minds, and their temperaments and aptitudes, will be pre-programmed in a great variety of outcomes of gene expression in nerve tissue development, but the same processes are also influenced by postnatal environments. Growing brains require cultivation by intimate communication with older human brains. A human brain after many years of life can be compared with a chess-board (of gigantic complexity) on which the layout of the pieces reflects the history and identity of one particular game.

It is of vital importance to keep all aspects of brain activity in mind when one, for example, sets out to understand and model the behaviour of a learner driver, or the changes in behaviour over the lifetime of a driver. For example, just consider how long the neural circuitry of an individual's brain will have been exposed to the shaping effects of the environment by the time he/she applies for a learner permit at, for say, the age of sixteen. In a learning phase, a driver will (and a driver model should) eventually progress from delayed avoidance responses to anticipatory avoidance responses. Some learning may perhaps be assimilated as a (apparent) set of driving rules (based on language capabilities) and some may come about explicitly through exposure to the actions of others.

5.2 Propositions

To conclude, based on the findings from the literature study reported in this dissertation, the author put forward a platform from where the issue of driver behaviour could be approached by combining the aspects related thereto from an engineering and psychological perspective with and based on neuroscience (involving neuroanatomy, neurophysiology, developmental biology and psychology) and a modelling strategy (for instance, connectionism) in order to yield quantitative driver models. The issue of driver behaviour has shown that it is complex and it is very clear that it should be approached in a holistic way, and therefore it is of utmost importance that a *combined* effort be made from the mentioned fields. It is uncommon that professionals in each of the above-mentioned fields have a real good understanding of the other fields affecting driver behaviour, and therefore the author, not pretending to be an expert, argues that such a union, if actively pursued, will be of significant value in transportation and all behavioural sciences. It should be clear that opposition against vigorously incorporating advances in neuroscience will constantly hamper valuable progress on a wide front in the behavioural sciences.

The wealth of to-date knowledge amassed in neuroscience lies ready to be tapped by researchers interested in explaining human driver behaviour, initially just through a synthesising effort. Of utmost importance to the success of such a research effort will be the extent to which collaboration is sought and established by investigators across boundaries of the mentioned traditional fields of research, willing to contribute to the development of a comprehensive (representational and computational) model of the driver. In order to strengthen and foster the proposed extension of the basis from which driver behaviour is modelled and understood, the field of traffic engineering is in need of being realigned through institutional re-engineering and broadening of its curricula to enable its investigators and students to participate in the proposed collaboration efforts.

In addition, the proposed extension of the knowledgebase of driver behaviour will impinge on the type of data and data-collection methodology required for calibrating such models in future. For example, the use of modern brain-imaging techniques will be invaluable in pinning down the neural correlates of particular driving subtasks, bearing in mind the extent of structural impacts on the brain of each individual driver, brought about by a lifetime of interaction with the environment. In essence, an important question will be how to read and make use of what is stored on the neural circuitry of a driver. As a concrete next step in applying neuroscientific knowledge in traffic engineering, the author proposes that supplementary work be conducted by a multi-disciplinary team to finalise the design and roll-out of an experiment to study the nature of environmental stimuli as instigators of aggression and road rage, based on the utility of brain imaging and (amygdala) activation.

Case studies mentioned in the literature study on the subject of connectionism demonstrate how modelling, based on the principles of computation in the brain, can mimic specific human behaviours. Once collaboration between investigators from neuroscience, psychology, traffic engineering, and computer science can be initiated, similar results in terms of driver behaviour will be achievable. In accordance to a criterion set by Michon (1985), the approach, as set out in this dissertation, is essentially at the individual level as far as its performance is concerned, but it is general to the extent that it describes human competence. That is, when applied to driving it could be stated as a general theory of driver behaviour, but when put to work it would generate an individual driver's history, depending on its learning experiences.

REFERENCES

Driver Behaviour

1. Åberg, L.; Engdahl, S.; Nilsson, E. (1989). *Höjda hastighetsböter. Effekter på förares kunskaper om bötesbelop och val av hastighet*. Transportforskningsberedningen, (TFB-meddelan-de nr 100).
2. Åberg, L.; Rimmò, P-A. (1998). *Dimensions of Aberrant Driver Behaviour*. Ergonomics, Vol., 41(1):39-56.
3. Abrahams, J.P.; Birren, J.E. (1973). *Reaction Time as a Function of Age and Behavioral Predisposition to Coronary Heart Disease*. Journal of Gerontology, Vol. 28:471-476.
4. Ackerman, P.L. (1988). *Determinants of Individual Differences during Skill Acquisition: Cognitive Abilities and Information Processing*. Journal of Experimental Psychology, Vol. 117:288-318.
5. Adams, J. (1985). *Smeed's Law, Seat Belts, and the Emperor's New Clothes.* In: L. Evans, R.C. Schwing, Eds., Human Behavior and Traffic Safety, Pp.193-248. Plenum Press, New York.
6. Adams, J.G.U. (1985). *Risk and Freedom: The Record of Road Safety Regulation*. Transport Publishing Projects, London.
7. Adams, J.R. (1970). *Personality Variables associated with Traffic Accidents*. Behavioural Research in Highway Safety, Vol. 1:3-18.
8. Ahadi, S.A.; Rothbart, M.K. (1994). *Temperament, Development, and the Big Five.* In: C. Halverson, G. Kohnstamm, R. Martin, Eds., The developing structure of temperament and personality from infancy to adulthood, pp.189-208. Erlbaum, Hillsdale, NJ.
9. Ajzen, I. (1991). *The Theory of Planned Behavior.*Organ. Behav. Human Decision Processes 50:179-211.
10. Ajzen, I.; Fishbein, M. (1980). *Understanding Attitudes and Predicting Social Behaviour.* Prentice Hall, Englewood-Cliffs, NJ.
11. Alexander, G.J.; Lunenfeld, H. (1984). *A User's Guide to Positive Guidance in Highway Control.* In: R. Easterby, H. Zwaga, Eds., Information Design, pp.351-383. Wiley, Chichester.

12. Allen, R.W.; McRuer, D.T. (1977). *Driver Steering Dynamics measured in a Car Simulator under a Range of Visibility and Road Marking Conditions*. Proceedings of the 13th Annual Conference on Manual Control, pp.180-196. Cambridge, MA; M.I.T.
13. Alloy, L.B.; Clements, C.M.; Koenig, L.J. (1993). *Perceptions of Control: Determinants and Mechanisms*. In: G. Weary, F. Gleicher, K.L. Marsch, Eds., Control Motivation and Social Cognition, pp.33-73. Springer, New York.
14. Alm, H. (1995). *Driving Simulators as Research Tools – A Validation Study based on the VTI Driving Simulator*. In: DRIVE II V2065: GEM Validation Studies – Appendix, Reference GEM/TR/TRC/MK950327, Work package 500, Deliverable No. 10, Rover, British Aerospace, Philips Research Laboratories, TNO Institute for Perception, Kara (COSILY), Acit Gmbh, TRC University of Groningen, University of Leeds.
15. Anderson, J.R. (1982). *The Acquisition of Cognitive Skill*. Psychological Review, Vol. 89:369-406.
16. Anderson, J.R. (1983). *The Architecture of Cognition*. Harvard University Press, Cambridge, MA.
17. Anderson, N.H. (1970). *Functional Measurement and Psychophysical Judgment*. Psychological Review. 77:153-170.
18. Andersson, B-E. (1987). *Ett led I Frigörelsen. (The Driver's License – Part of Liberation)*. In: K. Spolander, Young People and Traffic – An impossible Combination. NTF, Kista.
19. Armsby, P.; Boyle, A.J.; Wright, C.C. (1989). *Methods for Assessing Drivers' Perception of Specific Hazards on the Road*. Accid. Anal. and Prev., Vol. 21(1):45-60.
20. Arnett, J. (1990). *Drunk Driving, Sensation Seeking, and Egocentrism among Adolescents*. Personality and Individual Differences, Vol. 11:541-546.
21. Arnett, J. (1994). *Sensation Seeking: A New Conceptualization and a New Scale*. Personality and Individual Differences, Vol. 16:289-296.
22. Arnett, J.J.; Offer, D.; Fine, M.A. (1997). *Reckless Driving in Adolescence: 'State' and 'Trait' Factors*. Accid. Anal. and Prev., Vol. 29(1):57-63.
23. Arthur, W. Jr.; Graziano, W.G. (1996). *The Five-factor Model, Conscientiousness, and Driving Accident Involvement*. Journal of Personality, Vol.64:3. Duke University Press.
24. Arthur, W.; Doverspike, D. (1991). *Locus of control and auditory selective attention as predictors of driving accident involvement: A comparative longitudinal investigation.* Human Performance, Vol. 4:89-105.
25. Aschenbrenner, K.M.; Biehl, B.; Wurm, G.M. (1986). *Antiblockiersystem und Verkehrssicherheit: Ein Vergleich der Unfallbelastung von Taxen mit und ohne Antiblockersystem.* Teilbericht und die Bundesanstalt für Strassenwesen zum

Forschungsprojekt 8323: Einfluss der Risikokompensation auf die Wirkung von Sicherheitsmassnahmen, Mannheim, Germany.

26. Avolio, B.J.; Kroeck, K.G.; Panek, P.E. (1985). *Individual Differences in Information-processing Ability as a Predictor of Motor Vehicle Accidents*. Human Factors, Vol. 27(5):577-587.
27. Aylwin, S. (1985). *Structure in Thought and Feeling*. Methuen, London.
28. Bainbridge, L. (1983). *Ironies of Automation*. Automatica, 19:775-779.
29. Ball, K.; Beard, B.; Roenker, D.; Miller, R.; Griggs, D. (1988). *Age and Visual Search: Expanding the Useful Field of View*. J. Opt Soc Am A., Vol. 5:2210-2219.
30. Ball, K.; Owsley, C. (1991). *Identifying Correlates of Accident Involvement for the older Driver*. Human Factors 33:583-595.
31. Ball, K.; Owsley, C.; Beard, B. (1990). *Clinical Visual Perimetry underestimates Peripheral Field Problems in Older Adults*. Clin Vis Sci., Vol. 5:113-125.
32. Ball, K.; Owsley, C.; Sloane, M.E.; Roenker, D.L.; Bruni, J.R. (1993). *Visual Attention Problems as a Predictor of Vehicle Crashes in Older Drivers*. Investigative Ophthalmology and Visual Science, Vol. 34(11).
33. Ball, K.; Roenker, D.L.; Bruni, J.R. (1990). *Developmental Changes in Attention and Visual Search throughout Adulthood.* In: J.T. Enns, Ed., The development of attention: Research and theory, pp.489-508. New York: North-Holland.
34. Barickman, F.S.; Goodman, M.J. (1999) *In-Vehicle Portable Data Acquisition System*. Transportation Research Record 1689, TRB, pp. 1-8. National Research Council, Washington, D.C.
35. Barrett, G.B.; Alexander, R.A.; Forbes, B. (1973). *Analysis and Performance Requirements for Driving Decision making in Emergency Situations*. Technical Report no. DOT HS-800 867, Washington, DC.
36. Barrett, G.V.; Thornton, C.L. (1968). *Relationship between Perceptual Style and Driver Reaction to an Emergency Situation*. J. Appl. Psychol. 52:169-176.
37. Bartlett, F.C. (1948). *A Note on Early Signs of Skill Fatigue*. Air Ministry Flying Personnel Research Committee Report No. 703, Ministry of Defence, London.
38. Bath, S. (1992). *The Influence of Social Factors on the Exposure to Risk of Young Drivers: Predictors of High Involvement and No Involvement*. Presented at Canadian Sociology and Anthropology Association Annual Meeting, Charlottetown, P.E.I.
39. Baxter, J.S.; Macrae, C.N.; Manstead, A.S.R.; Stradling, S.G.; Parker, D (1990). *Attributional Biases and Driver Behaviour*. Social Behaviour, Vol. 5:185-192.

40. Beirness, D.J. (1993). *Do we really drive as we live? The Role of Personality Factors in Road Crashes*. Alcohol, Drugs and Driving, Vol. 9:129-143.
41. Beirness, D.J.; Simpson, H.M. (1988). *Lifestyle Correlates of Risky Driving and Accident Involvement among Youth*. Alcohol, Drugs and Driving, Vol. 4:193-204.
42. Ben-Ari, O.T.; Florian, V.; Mikulincer, M. (2000). *Does a Threat Appeal moderate Reckless Driving? A Terror Management Theory Perspective*. Accid. Anal. and Prev., Vol. 32:1-10.
43. Ben-David, G.; Lewin, I.; Haliva, Y.; Tel-Nir, L. (1972). *The Influence of Personal Communication on the Driving Behaviour of Private Motorists in Israel*. Accid. Anal. and Prev., Vol. 4:269-301.
44. Berg, H.; Eliasson, K.; Palmvist, J.; Gregersen, N.P. (1999). *Learner Drivers and Lay Instruction – How Socio-economic Standing and Lifestyle are reflected in Driving Practice for the Age of 16*. Transportation Research, Part F, pp.167-179. Elsevier Science Ltd.
45. Berger, R.J.; Persinger, G.S. (1980). *Survey of Public Perception of Highway Safety*. Automated Services Inc., McLean, VA.
46. Berlyne, D.E. (1969). *The Reward-value of Indifferent Stimulation*. In: J.T. Tapp, Ed., Reinforcement and Behaviour. Academic Press, New York.
47. Bertalanffy, L. (1968). *General System Theory*. G. Braziller, New York.
48. Bianchi, L. (1922). *The Mechanism of the Brain and the Function of the Frontal Lobes*. Livingstone, Edinburgh.
49. Birren, J.E. (1974). *Personality Stress takes its Toll*. Medical World News Review, Vol. 1:42-43.
50. Björkman, M. (1963). *An exploratory Study of Predictive Judgments in a Traffic Situation*. Scand. J. Psychol., Vol. 4:65-76.
51. Bjornskau, T. (1996). *Why are the 'safest' Norms, Attitudes and Types of Behaviour not typical for the safest Drivers*? Transport Reviews, Vol. 16:169-181.
52. Bjornskau, T.; Elvik, R. (1992). *Can Road Traffic Law Enforcement permanently reduce the Number of Accidents?* Accid. Anal. 24:507-520.
53. Blaauw, G.J. (1982). *Driving Experience and Task Demands in Simulator and Instrumented Car: A Validation Study*. Human Factors, Vol. 24:473-486.
54. Blockley, P.N.; Hartley, L.R. (1995). *Aberrant driving behaviour: errors and violations*. Ergonomics, Vol. 38:1759-1771.
55. Bonnie, R.J. (1985). *The Efficacy of Law as a Paternalistic Instrument*. Nebraska Symposium on Motivation, Vol. 29:131-211.

56. Bötticher, A.M.T.; Van der Molen, H.H. (1985). *Risicomodellen als Determinanten van Voorlichting en andere Verkeersveiligheidsmaatregelen*. Traffic Research Centre Report VK85-21, University of Groningen.
57. Bötticher, A.M.T.; Van der Molen, H.H. (1988). *Predicting Overtaking Behaviour on the Basis of the Hierarchical Risk Model for Traffic Participants.* In: J.A. Rothengatter, R.A. De Bruin, Eds., Road User Behaviour: Theory and Research, Pp.48-65. Van Gorcum, Assen.
58. Brackett, R.Q.; Edwards, G.P. (1977). *Comparative Evaluation of Speed Control Strategies*.Vol 1. Summary of results. Final Report. College Station, Texas Transportation Institute, TX.
59. Brackstone, M.; McDonald, M. (1995). *Modeling of Motorway Operations.* Transportation Research Record 1485, TRB, pp. 56-60. National Research Council, Washington, D.C.
60. Brackstone, M.; McDonald, M. (1996). *The Microscopic Modeling of Traffic Flow: Weaknesses and Potential Developments.* In: D.E. Wolf, M. Schreckenberg, A. Bachem, Eds., Workshop on Traffic and Granular Flow, pp. 151-166. HLRZ, Julich, Germany World Scientific, Singapore.
61. Brackstone, M.; McDonald, M. (2000). *Car Following: A Historical Review.* Transportation Research: Traffic Psychology and Behaviour (F), Vol. 1 and 2:181-196.
62. Brackstone, M.; McDonald, M.; Sultan, B. (1999) *Dynamic Bahavioral Data Collection Using an Instrumented Vehicle.* Transportation Research Record 1689, TRB, pp. 9-17. National Research Council, Washington, D.C.
63. Brehm, J.W. (1966). *A Theory of Psychological Reactance*. Academic, New York.
64. Brehm, S.S.; Brehm, J.W. (1981). *Psychological Reactance: A Theory of Freedom and Control*. Academic, New York.
65. Brehmer, B. (1980). *In One Word: Not from Experience*. Acta Psychologica, Vol. 45:223-241.
66. Brehmer, B. (1990). *Variable errors set a limit to adaptation*. Ergonomics, Vol. 33:1231-1240.
67. Brehmer, B.; Breedt, W. (1989). *Variable Errors set a Limit to Adaptation*. Commission of the European Communities Workshop on Errors in the Operation of Transport Systems, Cambridge.
68. Broadbent, D.E. (1958). *Perception and Communication*. New York: Pergamon Press.
69. Broadbent, D.E. (1971). *Decision and Stress*. Academic Press, London.
70. Brookhuis, K.A.; Brown, I.D. (1992). *Ergonomics and Road Safety*. Impact of science on society, 165:35-40.
71. Brookhuis, K.A.; De Vries, G.; De Waard, D. (1991). *The Effects of Mobile Telephoning on Driving Performance*. Accid. Anal. and Prev., Vol. 23:309-316.

72. Brookhuis, K.A.; De Waard, D. (1993). *The Use of Psychophysiology to assess Driver Status*. Ergonomics, 36:1099-1110.

73. Brookhuis, K.A.; De Waard, D. (1999). *Limiting Speed, towards an Intelligent Speed Adapter (ISA)*. Transportation Research Part F, Traffic Psychology and Behaviour, 2:81-90.

74. Brookhuis, K.A.; Van der Heijden, R.E.C.M. (1999). *Behavioural Analysis of Transport Automation*. Connekt Research Program 2000-2003.

75. Brown, I.D. (1970). *Effects of Prolonged Driving on Overtaking Criteria*. Ergonomics, Vol. 13:239-242.

76. Brown, I.D. (1982a). *Exposure and Experience are a confounded Nuisance in Research on Driver Behaviour*. Accid. Anal. and Prev., Vol. 14:345-352.

77. Brown, I.D. (1982b). *Driver Behaviour*. In: A.J. Chapman, F.M. Wade, H.C. Foot, Eds., Pedestrian Accidents. Wiley, Chichester.

78. Brown, I.D. (1990). *Driver's Margins of Safety considered as a Focus for Research on Error*. Ergonomics 33:1307-1314.

79. Brown, I.D. (1995). *Methodological Issues in Driving Fatigue Research*. In: L. Hartley, Ed., Fatigue and Driving, pp.155-166. Taylor and Francis, London.

80. Brown, I.D. (1997). *Prospects for Technological Countermeasures against Driver Fatigue*. Accid. Anal. and Prev., Vol. 29(4):525-531.

81. Brown, I.D.; Copeman, A.K. (1975). *Drivers' Attitudes to the Seriousness of Traffic Offences considered in Relation to the Design of Sanctions*. Accid. Anal. and Prev., Vol. 7:15-26.

82. Brown, I.D.; Groeger, J.A. (1988). *Risk Perception and Decision Taking during the Transition between Novice and Experienced Driver Status*. Ergonomics, Vol. 31(4):585-597.

83. Brown, I.D.; Groeger, J.A.; Biehl, B. (1987). *Is Driver Training contributing enough towards Road Safety*? In: J.A. Rothengatter, R.A. De Bruin, Eds., Road Users and Traffic Safety, pp.135-156. Van Gorcum, Assen/Maastricht.

84. Brown, I.D.; Poulton, E.C. (1961). *Measuring the Spare 'Mental Capacity' of Car Drivers by a Subsidiary Task*. Ergonomics, Vol. 4:35-40.

85. Brown, I.D.; Tickner, A.H.; Simmonds, D.C.V. (1969). *Interference between Concurrent Tasks of Driving and Telephoning*. Journal of Applied Psychology, Vol. 53:419-424.

86. Brunstein, J.C.; Gollwitzer, P.M.; (1996). *Effects of Failure on Subsequent Performance, the Importance of Self-defining Goals*. Journal of Personality and Social Psychology, pp.395-407.

87. Burg, A. (1970). *The Stability of Driving record over Time*. Accid. Anal. and Prev., Vol. 2:57-65.

88. Burnham, G.O.; Seo, J.; Bekey, G.A. (1974). *Identification of Human Driver Models in Car Following*. IEEE Transactions on automatic control. Vol. AC-19, No. 6.

89. Burrus, M.E.; Dewing, W.; Hancock, P. (1994). *Human Factors Issues of Expanded Technology in Automation of Driving Tasks*. Paper presented and the 1st Automation Technology and Human Performance Conference, Washington, DC.

90. Casey, S.M.; Lund, A.K. (1992). *Changes in Speed and Speed Adaptation Following Increase in National Maximum Speed Limit.* Journal of Safety Research, Vol. 23:135-146.

91. Cattell, R.B.; Eber, H.W. (1964). *Handbook for the 16 Personality Factor Questionnaire "The 16 P.F. Test".* Western Psychological Services Publishers, Beverly Hills, CA.

92. Cavallo, V.; Brun-Dei, M.; Laya, O.; Naboit, M. (1988). *Perception and Anticipation in Negotiating Curves: The Role of Driving Experience*. In: A.G. Gale, M.H. Freeman, C.M. Haslegrave, P. Smith, S.P. Taylor, Eds., Vision in Vehicles II, pp.365-374. Amsterdam, North-Holland.

93. Ceder, A.; May, A.D. (1976). *Further Evaluation of Single and Two Regime Traffic Flow Models.* Transportation Research Record, Vol. 567:1-30.

94. Cerella, J. (1990). *Aging and Information-processing Rate*. In: J.E. Birren, K.W. Schaie, Eds., Handbook of the Psychology of Aging, 3rd edition, pp.201-233. Academic Press, New York.

95. Chapanis, A.; Garner, W.R.; Morgan, C.T. (1949). Applied Experimental Psychology. Wiley, New York.

96. Chase, L.J.; Mills, N.H. (1973). *Status of Frustrator as a Facilitator of Aggression: A brief Note*. J of Psychology, Vol. 84(2):225-226.

97. Chliaoutakis, J.E.; Gnardellis, C.; Drakou, I.; Darviri, C.; Sboukis, V. (2000). *Modelling the Factors to the Seatbelt Use by the Young Drivers of Athens*. Accid. Anal. and Prev., Vol. 32:815-825.

98. Christol, J.; Dorel, M.; Queinnec, Y.; De Terssac, G. (1979). *Horaires de Travail et Règulation des Donduites*. Le Travail Humain, Vol. 42:211-229.

99. Clay, D. (1987). *Driver Attitude and Attribution in Relation to Accident Involvement*. Unpublished M.Sc. dissertation, Cranfield Institute of Technology, Cranfield.

100. Cohen, A.S. (1981). *Car Drivers Pattern of Eye Fixations on the Road and in the Laboratory*. Perceptual and Motor Skills, Vol. 52:515-522.

101. Cole, B.L.; Hughes, P.K. (1990). *Drivers don't Search: They just Notice.* Proceedings of the 1st International Conference on Visual Search, University of Durham, England. Taylor and Francis, London.

102. Combs, B.; Slovic, P. (1979). *Causes of Death: Newspaper Coverage and Biased Judgements*. Journalism Quarterly, Vol. 56:837-843.

103. Comte, S.L. (1996). *Response to Automatic Speed Control in Urban Areas: A Simulator Study*. Working Paper no. 477. Institute for Transport Studies, University of Leeds, Leeds.

104. Comte, S.L. (1998). *Evaluation of In-car Speed Limiters: A Simulator Study*. WP 3.2.1, EC project MASTER (RO-96-SC.202). University of Leeds, Leeds.

105. Comte, S.L. (2000). *New Systems: New Behaviour?* Transportation Research Part F, Vol. 3:95-111. Elsevier Science Ltd.

106. Congress, N. (1994). *The Automated Highway System: An Idea whose Time has come*. Public Roads On-Line.

107. Connolly, T.; Åberg, L. (1993). *Some Contagion Models of Speeding*. Accid. Anal. and Prev., Vol. 25:57-66.

108. Conybeare, J.A.C. (1980). *Evolution of Automobile Safety Regulation: The Case of Compulsory Seat Belt Legislation in Australia*. Policy Sciences, Vol. 12:27-39.

109. Cooper, P.J.; Pinili, M.; Chen, W. (1995). *An Examination of the Crash Involvement Rates of Novice Drivers Aged 16 to 55*. Accid. Anal. and Prev., Vol. 27(1):89-104.

110. Corbett, C. (1995). *Road Traffic Offending and the Introduction of Speed Cameras in England: The First Self-report Survey*. Accid. Anal. and Prev., Vol. 27:345-354.

111. Cosnier, J. (1977). *Communication non Verbale et Langage*. Psychologie Mèdicale, Vol. 9:2033-2049.

112. Cownie, A.R.; Calderwood, J.H. (1966). *Feedback in Accident Control*. Operational Research Quarterly, Vol.17:253-262.

113. Crandon, I.W.; Branday, J.M.; Simeon, D.T.; Rhoden, A.; Thompson, H.; Carpenter, R. (1996). *The Prevalence of Seat Belt Use in Jamaica. An Observational Study*. West Indian Journal, Vol. 45(1):31-33.

114. Crossman, E.R.F.W.; Cooke, S.E. (1974). *Manual Control of Slow Response Systems*. In: E. Edwards, F.P. Lees, Eds., The Human Operator in Process Control. Taylor and Francis, London.

115. Crossman, E.R.F.W.; Szostak, H. (1968). *Man-machine Models for Car Steering*. Proceedings of the 4th Annual Conference on Manual Control, pp.275-289.Ann Arbor, MI: University of Michigan.

116. Crundall, D.E.; Underwood, G. (1998). *Effects of Experience and Processing Demands on Visual Information Acquisition in Drivers*. Ergonomics, Vol. 41(4):448-458.

117. Cumming, R.W. (1963). *The Analysis of Skills in Driving*. Paper presented at Meeting of the Highways and Traffic Engineering Branch of the Institution of Engineers, Melbourne, Australia.

118. Davies, B.T.; Watts, J.M. Jr. (1969). *Preliminary Investigation of between Movement Time* en *Brake and Accelerator Pedals in Automobiles.* Human Factors, Vol. 11, No. 4:407-410.

119. Davies, B.T.; Watts, J.M. Jr. (1970). *Further Investigation of Movement Time between Brake and Accelerator Pedals in Automobiles*. Human Factors, Vol. 12, No. 6:559-561.

120. Davis, D.R. (1958). *Human Errors and Transport Accidents*. Ergonomics, Vol. 2:24-33.

121. De Waard, D.; Van der Hulst, M.; Hoedemaeker, M.; Brookhuis, K.A. (1999). *Driver Behavior in an Emergency Situation in the Automated Highway System*. Transportation Human Factors, 1:67-82.

122. Dean, T.; Kanazawa, K. (1988). *Probabilistic Temporal Reasoning*. Proceedings AAAI-88, Minneapolis, Minnesota.

123. Deffenbacher, J.L.; Oeting, E.R.; Lynch, R.S. (1994). *Development of a Driving Anger Scale*. Psychological Reports, Vol. 74(1):83-91.

124. Deiner, E.; Fraser, S.C.; Beaman, A.L.; Kelem, R.T. (1976). *Effects of Deindividuation Variables on Stealing among Halloween Trick-or-treaters.*. J of Personality and Social Psychology, Vol. 35:178-183.

125. Dejong, W.; Atkin, C.K. (1995). *A Review of National Television, PSA Campaigns for preventing Alcohol Impaired Driving, 1987-1992*. Journal of Public Health Policy, Vol. 16:59-80.

126. Delhomme, P. (1995). *Evaluation de Ses Propos Capacitès de Conduite et Activitè de Condu.* Revue Transport et Sècuritè, Vol. 48:39-51.

127. Delhomme, P.; Meyer, T. (1998). *Control Motivation and Young Drivers' Decision Making*. Ergonomics, Vol. 41(3):373-393.

128. Delvolvè, N. (1987). *Les Activitès Collatèrales: Repère de L'instabilitè de L'homme au Travail*. Thesis, Paul Sabatier University, Toulouse.

129. Denton, G.G. (1963). *A Subjective Scale of Speed when Driving a Motor Vehicle*. Laboratory Note LN/443/GGD, Department of Scientific and Industrial Research, Road Research Laboratory.

130. Digman, J.M.; Inouye, J. (1986). *Further Specification of the Five Robust Factors of Personality*. Journal of Personality and Social Psychology, Vol. 50:116-123.

131. Doderlein, J.M. (1987). *Introduction*. In: W.T. Singleton, J. Hovden, Eds., Risk and Decisions,pp.1-9. Wiley, Chichester.

132. Doherty, S.T.; Andrey, J.C.; MacGregor, C. (1998). *The Situational Risks of Young Drivers: The Influence of Passengers, Time of Day and Day of Week on Accident Rates*. Accid. Anal. and Prev., Vol. 30:45-52.

133. Dollard, J.; Doob, L.W.; Miller, N.P.; Mowrer, O.H.; Sears, R.R. (1939). *Frustration and Aggression.* Yale University Press, New Haven, CN.

134. Donges, E. (1978). *A Two-level Model of Driver Steering Behavior*. Human Factors, Vol. 20:691-707.

135. Donovan, D.M.; Marlatt, G.A.; Salzberg, P.M. (1983). *Drinking Behaviour, Personality Factors and High-risk Driving: A Review and Theoretical Formulation.* J of Studies on Alcohol, Vol. 44(3):395-428.

136. Donovan, D.M.; Umlauf, R.L.; Salzberg, P.M. (1988). *Derivation of Personality Subtypes among High-risk Drivers.* Alcohol, Drugs and Driving, Vol. 4:233-244.

137. Draskóczy, (1993). *Mandatory Safety Quality Assurance*. Hopes Deliverable, no. 11. University of Lund, Department of Traffic Planning and Engineering, Lund.

138. Duncan, J. (1990). *Goal Weighting and the Choice of Behaviour in a Complex World.* Ergonomics, Vol. 33:1265-1280.

139. Duncan, J.; Williams, P.; Brown, I. (1991a). *Components of Driving Skill: Experience does not mean Expertise*. Ergonomics, Vol. 34(7):919-937.

140. Duncan, J.; Williams, P.; Nimmo-Smith, I.; Brown, I. (1991b). *The control of Skilled Behaviour: Learning, Intelligence and Distraction*. In: D. Meyer, S. Kornblum, Eds., Attention and Performance XVI. Erlbaum, Hillsdale, NJ.

141. Easterbrook, J.A. (1959). *The Effect of Emotion on Cue Utilization and the Organization Behavior*. Psychological Review, Vol. 66:183-201.

142. Echterhof, W. (1988). *Personal Communication.*

143. Edelberg, R. (1972). *Electrical Activity of the Skin: Its Measurement and Uses in Psychophysiology.* In: N.S. Greenfield, R.A. Sternbach, Eds., Handbook of Psyhophysiology. Holt, Rinehart and Winston, New York.

144. Edland, E.; Svenson, O. (1993). *Judgement and Decision Making under Time Pressure*. Human Judgement and Decision Making, pp.27-40. Plenum, New York.

145. Elander, J.; West, R.; French, D. (1993). *Behavioral Correlates of Individual Differences in Road-traffic Crash Risk: An Examination of Methods and Findings.* Psychological Bulletin, Vol. 113:279-294.

146. Ellison, P.A.; Govern, J.M.; Petri, H.L.; Figler, M.H. (1995). *Anonymity and Aggressive Driving Behavior: A Field Study*. J of Social Behavior and Personality, Vol. 10(1):265-272.

147. Elvik, R.; Vaa, T.; Ostvik, E. (1989). *Traffiksikkerhetshandbok*. Revidert utgave. Transportokonomisk institutt, Oslo.

148. Engdahl, S.; Nilsson, E. (1983). *Trafikövervakningens långsiktiga effekter på hastighetsövertredelser*. I TFD-rapport 1983:13, Trafikövervakningens långsiktiga effekter på olyckor och beteeden. Transportforskningsdelegationen, Stockholm.

149. Engel, F.L. (1971). *Visual Conspicuity, Directed Attention and Retinal Locus*. Vision Research, Vol. 11:563-576.

150. Ericsson, K.A.; Polson, P.G. (1988). *A Cognitive Analysis of Exceptional Memory for Restaurant Orders*. In: M.T.H. Chi, R. Glaser, M.J. Farr, Eds., The Nature of Expertise. Erlbaums, Hillsdale, NJ.

151. Ericsson, K.A.; Simon, H.A. (1980). *Verbal Reports as Data*. Psychological Review, Vol. 87:215-251.

152. European Transport Safety Council (1996). *Seat Belts and Child Restraints. Increasing Use and Optimising Performance.* Brussels, Belgium.

153. Evans, L. (1985). *Driver Behaviour revealed in Relations involving Car Mass*. In: L. Evans, R.C. Schwing, Eds., Human Behaviour and Traffic Safety. Plenum Press, New York.

154. Evans, L. (1986b). *Comments on Wilde's Notes on 'Risk Homeostasis Theory and Traffic Accident Data'*. Risk Analysis, Vol. 6:103-107.

155. Evans, L. (1991). *Traffic Safety and the Driver*. Van Nostrand Reinhold, New York.

156. Evans, L. (1996). *Safety-belt Effectiveness: The Influence of Crash Severity and Selective Recruitment*. Accid. Anal. and Prev., Vol. 28(4):423-433.

157. Eysenck, H.J. (1965). *Fact and Fiction in Psychology*. Penguin, Harmondsworth, U.K.

158. Eysenck, H.J. (1967). *The Biological Basis of Personality*. Thomas, Springfield,Ill.

159. Eysenck, H.J. (1983). *A Biometrical-genetical Analysis of Impulsive and Sensation Seeking Behavior*. In: M. Zuckerman, Ed., Biological bases of sensation seeking, impulsivity, and anxiety. pp.1-35. Lawrence Erlbaum Associates, Hillside, NJ.

160. Eysenck, M.W. (1982). *Attention and Arousal: Cognition and Performance*. New York: Springer-Verlag.

161. Fakhar, S.; Vallet, M.; Olivier, D.; Baez, D. (1991). *La Posture Corporelle comme Indicateur de Fatigue du Conducteur*. In: M. Vallet, Ed., Le Maintien de la Vigilance dans les Transports. Transports et Communication, pp.151-157. Paradigme, Lyon.

162. Fancher, P.S.; Bareket, Z.; Bogard, S. (2001). *Modeling Driver Behavior using Mind's Eye Coordinates*. Transportation Research Board 80th Annual Meeting, Washington, D.C.

163. Farber, E.; Silver, C.A. (1967). *Conceptualization of Overtaking and Passing on Two-lane Rural Roads II*. Report 1-193-11, The Franklin Institute Research Laboratories.

164. Farber, E.; Silver, C.A. (1967). *Knowledge of Oncoming Car Speed as Determiner of Driver's Passing Behavior*. Highway Research Record, Vol. 195:52-65.

165. Farrow, J.A.; Brissing, P. (1990). *Risk for DWI: A New Look at Gender Differences in Drinking and Driving Influences, Experiences and Attitudes among New Adolescent Drivers*. Health Education Quarterly Sum. Vol. 17(2):213-221.

166. Finn, P.; Bragg, B.W.E. (1986). *Perception of the Risk of an Accident by Young and Older Drivers*. Accid. Anal. and Prev., Vol. 18(4):289-298.

167. Fischhoff, B. (1985). Issues in Science and Technology, Vol. 2:38.

168. Fischhoff, B.; MacGregor, D. (1983). Risk Analysis, Vol. 3:229.

169. Fischhoff, B.; Slovic, P.; Lichtenstein, S. (1979). Environment, Vol. 21:17,32.

170. Fishbein, M.; Ajzen, I. (1975). *Belief, Attitude, Intention and Behaviour: An Introduction to Theory and Research*. Addison-Wesley, Reading MA.

171. Fisk, A.D.; Ackerman, P.L.; Schneider, W. (1987). *Automatic and Controlled Processing Theory and its Applications to Human Factors Problems*. In: P.A. Hancock, Ed., Human factors psychology. New York: North-Holland.

172. Fisk, A.D.; Oransky, N.A.; Skedvold, P.R. (1988). *Examination of the Role of "Higher-order" Consistency in Skill Development*. Human Factors 30:567-581.

173. Fisk, A.D.; Schneider, W. (1983). *Category and Word Search: Generalizing Search Principles to Complex Processing*. J. Exp. Psychol. Learn. Mem. Cogn. 9:117-195.

174. Fisk, A.D.; Schneider, W. (1984). *Task versus Component Consistency in Automatic Process Development: Consistent Attending versus Consistent Responding*. Bulletin of the Psychonomic Society 22:330-332.

175. Fiske, S.E.; Taylor, S.T. (1984). *Social Cognition*. Addison-Wesley, Reading, MA.

176. Fitts, P.M.; Posner, M.I. (1967). *Human Performance*. Brookscole Publishing Company, Belmont, California.

177. Fozard, J.L. (1990). *Vision and Hearing in Aging*. In: J.E. Birren, K.W. Schaie, Eds., Handbook of the Psychology of Aging, 3rd edition, pp.150-170. Academic Press, New York.

178. Friedland, N.; Keinan, G.; Regev, Y. (1992). *Controlling the Uncontrollable: Effects Stress on Illusory Perception of Controllability*. Journal of Personality and Social Psychology, Vol. 63:923-931.

179. Friedman, H.S.; Tucker, J.S.; Schwartz, J.E.; Martin, L.R.; Tomlinson-Keasey, C.; Wingard, D.L.; Criqui, M.H. (1995). *Childhood Conscientiousness and Longevity: Health Behavior and Cause of Death*. Journal of Personality and Social Psychology, Vol. 68:696-703.

180. Friedman, M.; Rosenman, R.H. (1959). *Association of Specific Overt Behavior Pattern with Blood and Cardiovascular Findings*. Journal of the American Medical Association, Vol. 159:1286-1296.

181. Fuller, R. (1984). *Conceptualisation of Driving Behaviour as Threat Avoidance*. Ergonomics 27:1139-1155.

182. Fuller, R. (1988). *On Learning to make Risky Decisions*. Ergonomics, Vol. 31(4):519-526.

183. Fuller, R. (1988). *Predicting what a Driver will do: Implications of the Threat-Avoidance Model of Driver Behaviour.* In: J.A. Rothengatter, R.A. De Bruin, Eds., Road User Behaviour: Theory and Research., pp.93-105. Van Gorcum, Assen.

184. Fuller, R. (1988b). *Psychological Aspects of Learning to Drive*. In: J.A. Rothengatter, R.A. de Bruin, Eds., Road User Behaviour, pp.527-537. Van Gorcum, Assen.

185. Fuller, R. (1991). *Behavior Analysis and Unsafe Driving: Warning – Learning Trap Ahead*! Journal of Applied Behavior Analysis, Vol. 24:73-75.

186. Fuller, R.G.C. (1981). *Determinants of Time Headway adopted by Truck Drivers*. Ergonomics, Vol. 24:463-474.

187. Furnham, A. (1988). *Lay Theories*. Oxford.

188. Ganton, N.; Wilde, G.J.S. (1971). *Verbal Rating of Estimated Danger by Drivers and Passengers as a Function of Driving Experience*. Studies of Safety in Transport, Queens University, Kingston Ontario.

189. Gardner, D.J.; Rockwell, T.H. (1983). *Two Views of Motorist Behavior in Rural Freeway Construction and Maintenance Zones: The Driver and the State Highway Patrolman*. Human Factors, Vol. 25:415-424.

190. Geller, E.S. (1990). *Preventing Injuries and Death from Vehicle Crashes.* In: J. Edwards; R.S. Tindale; L. Heath; E.J. Posavac, Eds., Social Influence Processes and Prevention, Pp.249-277. Plenum, New York.

191. Gibson, J.J. (1966). *The Senses considered as Perceptual Systems*. Boston: Houghton Mifflin.

192. Gibson, J.J.; Crooks, L.E. (1938). *A Theoretical Field-analysis of Automobile Driving*. Am. J. Psychol. 51:453-471.

193. Godthelp, H. (1986). *Vehicle Control during Curve Driving*. Human Factors, Vol. 28(2):211-221.

194. Godthelp, H. (1988). *The Limits of Path Error-neglecting in Straight Lane Driving*. Ergonomics, Vol. 31(4):609-619.

195. Godthelp, H.; Konings. H. (1981). *Levels of Steering Control: Some Notes on the Time-to-line Crossing Concept as related to Driving Strategy*. Proceedings of the First European Annual Conference on Human Decision Making and Manual Control, pp.343-357. Delft. The Netherlands.

196. Godthelp, H.; Milgram, P.; Blaauw, G.J. (1984). *The Development of a Time-related Measure to describe Driving Strategy*. Human Factors, Vol. 26:257-268.

197. Godthelp, J. (1985). *Precognitive Control: Open and Closed Loop Steering in a Lane Change Manoeuvre*. Ergonomics, Vol. 28:1419-1438.

198. Goldberg, D.E. (1989). *Genetic Algorithms in Search, Optimization, and Machine Learning.* Addison-Wesley Publishing Company, New York.

199. Goldberg, L.R. (1993). *The Structure of Phenotypic Personality Traits.* American Psychologist, Vol. 48:26-34.

200. Goldberg, L.R.; Rosolack, T.K. (1994). *The Big-Five Factor Structure as an Integrative Framework: An Empirical Comparison with Eysenck's P-E-N Model.* In: C. Halverson, G. Kohnstamm, R. Martin, Eds., The developing structure of temperament and personality from infancy to adulthood, pp.7-36. Erlbaum, Hillsdale, NJ.

201. Goodenough, D.R. (1976). *A Review of Individual Differences in Field Dependence as a Factor in Auto Safety*. Human Factors, Vol. 18:53-62.

202. Gopher, D.; Kahneman, D. (1971). *Individual Differences in Attention and the Prediction of Flight Criteria*. Percep. Mot. Skills 33:1335-1342.

203. Gray, J.A. (1981). *A Critique of Eysenck's (1981) Theory of Personality.* In: H.J. Eysenck, Ed., A Model for Personality. Springer, New York.

204. Greening, L.; Chandler, C.C. (1997). *Why it can't happen to me: The Base Rate matters, but overestimating Skill leads to Underestimating Risk.* Journal of Applied Social Psychology, Vol. 27:760-780.

205. Gregersen, N.P. (1994). *Systematic Co-operation between Driving Schools and Parents in Driver Education, an Experiment.* Accid. Anal. and Prev., Vol. 26:453-461.

206. Gregersen, N.P. (1996c). *Young Drivers' Overestimation of Their Own Skill – An Experiment on the Relation between Training Strategy and Skill*. Accid. Anal. and Prev., Vol. 28:243-250.

207. Gregersen, N.P.; Berg, H-Y. (1993). *Lifestyle and Accidents among Young Drivers.* Accid. Anal. and Prev., Vol. 26:297-303.

208. Gregersen, N.P.; Bjurulf, P. (1996a). *Young Novice Drivers: Towards a Model of Their Accident Involvement*. Accid. Anal. and Prev., Vol. 28(2):229-241.

209. Gregersen, N.P.; Brehmer, B.; Morén, B. (1996b). *Road Safety Improvement in Large Companies. An Experimental Comparison of Different Measures*. Accid. Anal. and Prev.

210. Groeben, N.; Westmeyer, H. (1975). *Kriterien Psychologischer Forschung*. Juventa, München.

211. Groeger, J.A. (1990). *Drivers' Errors in, and out of, Context*. Ergonomics 33:1432-1430.

212. Groeger, J.A.; Brady, S.J. (1999). *Tau Dot or not?* Paper given at the Eighth International Conference on Vision in Vehicles, Boston MA.

213. Groeger, J.A.; Chapman, P.R. (1990). *Errors and Bias in Assessments of Danger and Frequency of Traffic Situations*. Ergonomics, Vol. 33(10/11):1349-1363.

214. Groeger, J.A.; Rothengatter, J.A. (1998). *Traffic Psychology and Behaviour.* Transportation Research (F), Vol. 1:1-9.

215. Gugerty, L.J. (1997). *Situation Awareness during Driving: Explicit and Implicit Knowledge in Dynamic Spatial Memory.* Journal of Experimental Psychology: Applied, Vol. 3:42-66.

216. Gulian, E.; Glendon, A.I.; Matthews, G.; Davies, D.R.; Debney, L.M. (1990). *The Style of Driving*. Work and Stress, Vol. 4:7-16.

217. Gulian, E.; Matthews, G.; Glendon, A.I.; Davies, D.R.; Debney, L.M. (1989). *Dimensions of Driver Stress*. Ergonomics, Vol. 32:585-602.

218. Hacker, W.; Richter, P. (1980). *Psychische Fehlbeanspruchung: Psychische Ermüdung, Monotonie, Sättigung und Stress*. In: W. Hacker, Ed., Spezielle Arbeits- und Ingenieurspychologie in Einzeldarstellungen. VEB Deutscher Verlag der Wissenschaften, Berlin.

219. Hada, H. (1994). *Drivers' Visual Attention to In-vehicle Displays: Effects of Display Location and Road Type.* Report No. UMTRI-94-9, The University of Michigan Transportation Research Institute, Ann Arbor, MI.

220. Häkkinen, S. (1963). *Estimation of Distance and Velocity in Traffic Situations*. Report no. 3, Institute of Occupational Health, Helsinki, Finland.

221. Hale, A.R.; Glendon, A.I. (1987). *Individual Behaviour in the Control of Danger*. Elsevier, Amsterdam.

222. Hale, A.R.; Hale, M. (1970). *Accidents in Perspective*. Occupational Psychology, Vol. 44:115-122.

223. Hale, A.R.; Quist, B.W.; Stoop, J. (1988). *Errors in Routine Driving Tasks: A Model and Proposed Analysis Technique*. Ergonomics, Vol. 31(4):631-641.

224. Hale, A.R.; Stoop, J.; Hommels, J. (1990). *Human Error Models as Predictors of Accident Scenarios for Designers in Road Transport Systems*. Ergonomics 33:1377-1388.

225. Hämäläinen, V. (1988). *Vuorovaikutus, nopeus ja koetut riskit (Drivers' Interaction, Speed and Fears)*. The Central Organization for Traffic Safety in Finland, Helsinki, Finland.

226. Hancock, P.A. (1999). *Is Car Following the Real Question – are Equations the Answer?* Transportation Research (F), Vol. 2:197-199. Elsevier Science Ltd.

227. Hancock, P.A.; Parasuraman, R. (1992). *Human Factors and Safety in the Design of Intelligent Vehicle-Highway Systems (IVHS)*. Journal of Safety Research, 23:181-198.

228. Hancock, P.A.; Scallen, S.F. (1999). *The Driving Question.* Transportation Human Factors, Vol. 1:47-55.

229. Hansen, C.P. (1989). *A Causal Model of the Relationship among Accidents, Biodata, Personality, and Cognitive Factors.* Journal of Applied Psychology, Vol. 74:81-90.

230. Harano, R.M.; Peck, R.C.; McBride, R.S. (1975). *The Prediction of Accident Liability through Biographical Data and Psychometric Tests*. J. Safety Res. 7:16-52.

231. Harms, L. (1994). *Driving Performance on a Real Road and in a Driving Simulator: Results of a Validation Study*. In: A.G. Gale, Ed., Vision in Vehicles, Vol. V. Elsevier, North Holland.

232. Hauber, A.R. (1980). *The Social Psychology of Driving Behaviour and the Traffic Environment: Research on Aggressive Behaviour in Traffic*. Int. Review of Applied Psychology, Vol. 29(4):461-474.

233. Hauer, E.; Ahlin, F.J.; Bowser, J.S. (1982). *Speed Enforcement and Speed Choice*. Accid. Anal. and Prev., Vol. 14:267-278.

234. Hayes-Roth, B.; Hayes-Roth, F. (1979). *A Cognitive Model of Planning*. Cognitive Science, Vol. 3:275-310.

235. Heino, A.; Van den Molen, H.H.; Wilde, G.J.S. (1992). *Risk Homeostasis Process in Car Following Behaviour: Individual Differences in Car Following and Perceived Risk*. Report VK 92-02. Rijksuniversiteit Groningen Haven, The Netherlands.

236. Helander, M. (1978). *Applicability of Drivers' Electrodermal Response to the Design of the Traffic Environment*. Journal of Applied Psychology, Vol. 63:481-488.

237. Helander, M.G. (1975). *Physiological Reactions of Drivers as Indicators of Road Traffic Demand.* Transportation Research Record 530, TRB, pp. 1-17. National Research Council, Washington, D.C.

238. Hella, F. (1987). *Is the Analysis of Eye Movement Recording a Sufficient Criterion for Evaluating Automobile Instrument Panel Design?* In: J.K. O'Regan, A. Lèvy-Schoen, Eds., Eye-movements: From physiology to cognition, pp.555-561. Elsevier, Amsterdam

239. Helliar-Symons, R.D. (1983). *Automatic Close-following Warning Sign at Ascot.* Transport and Road Research Laboratory, Report 1095, UK.

240. Helson, H. (1971). *Adaptation-Level Theory: 1970 and After*. In: M.H. Appley, Ed., Adaptation-Level Theory: A Symposium, New York.

241. Hemenway, D.; Solnick, S.J. (1993). *Fuzzy Dice, Dream Cars and Indecent Gestures: Correltates of Driver Behaviour*? Accid. Anal. and Prev., Vol. 25:161-170.

242. Henderson, J.M.; Pollatsek, A.; Rayner, K. (1987). *Effects of Foveal Priming and Extra Foveal Preview on Object Identification*. Journal of Experimental Psychology: Human Perception and Performance, Vol. 13:449-463.

243. Henderson, J.M.; Pollatsek, A.; Rayner, K. (1989). *Covert Visual Attention and Extrafoveal Information Use during Object Identification*. Perception and Psychophysics, Vol. 45:196-208.

244. Hermansson, H-E. (1988). *Fristadens Barn (Young People in Search of Refuge)*. Daidalos, Göteborg.

245. Hilakivi, I.; Veilahti, J.; Asplund, P.; Sinivuo, J.; Laitinen, L.; Koskenvuo, K. (1989). *A Sixteen-factor Personality Test for Predicting Automobile Driving Accidents of Young Drivers*. Accid. Anal. and Prev., Vol. 21(5):413-418.

246. Hills, B.L. (1980). *Vision, Visibility, and Perception in Driving.* Perception 9:183-216.

247. Hodgdon, J.; Bragg, B.W.E.; Finn, P. (1981) *Young Driver Risk-taking Research: The State of the Art*. National Highway Traffic Safety Administration, National Technical Information Service, Springfield, VA.

248. Hoffmann, E.R. (1968). *Detection of Vehicle Velocity Changes in Car Following*. Vol. 4(1):821-837. Australian Road Research Board.

249. Hoffmann, E.R.; Mortimer, R.G. (1994). *Drivers' Estimates of Time to Collision*. Accid. Anal. and Prev., Vol. 26:511-520.

250. Hoffmann, E.R.; Mortimer, R.G. (1996). *Scaling Relative Differences between Vehicles*. Accid. Anal. and Prev., Vol. 28:415-421.

251. Hogema, J.H. (1999). *Modeling Motorway Driving Behavior*. Transportation Research Record 1689.

252. Holland, C.A. (1993). *Speed and Distance Estimation in Elderly Pedestrians*. Paper presented at British Psychological Society Cognitive Section Conference, Cambridge.

253. Holland, C.A.; Conner, M.T. (1996). *Exceeding the Speed Limit: An Evaluation of the Effectiveness of a Police Intervention*. Accid. Anal. and Prev., Vol. 28:587-597.

254. Hool, J.N.; Maghsoodloo, S.; Veren, A.D.; Brown, D.B. (1983). *Analysis of Selective Enforcement Strategy Effects on Rural Alabama Traffic Speeds*. Transport Research Record 910:74-81.

255. Horne, J.A.; Reyner,, L.A. (1995).*Falling asleep at the Wheel*. U.K. Transport Research Laboratory Report No. 168, Crowthorne, Berkshire, U.K.

256. Horvath, P.; Zuckerman, M. (1993). *Sensation Seeking, Risk Appraisal, and Risky Behavior*. Personality and Individual Differences, Vol. 14:41-52.

257. Howard, K.R. (1997). *Unjamming Traffic with Computers: Insights gleaned from Realistic Simulations are already moving from Computer Screens to Asphalt.* Scientific America.

258. Howarth, C. (1988). *The Relationship between Objective Risk, Subjective Risk and Behaviour*. Ergonomics, Vol. 31(4):527-535.

259. Hoyer, W.; Plude, D. (1982). *Aging and the Allocation of Attentional Resources in Visual Information Processing*. In: R. Sekuler, D. Kline, K. Dismukes, Eds., Aging and Human Visual Function, pp.245-263. Liss, New York.

260. Hoyos, C.G. (1988). *Mental Load and Risk in Traffic Behaviour*. Ergonomics, Vol. 31(4):571-584.

261. Hughes, P.K.; Cole, B.L. (1984). *Search and Attention Conspicuity of Road Traffic Control Devices*. Australian Road Research, Vol. 14:1-9.

262. Hughes, P.K.; Cole, B.L.(1986). *What attracts Attention when Driving?* Ergonomics, Vol. 29(3):377-391.

263. Huguenin, R.D. (1988). *The Concept of Risk and Behaviour Models in Traffic Psychology*. Ergonomics, Vol. 31(4):557-569.

264. Hunter, W.W.; Stewart, J.R.; Stutts, J.C.; Rodgman, E.A. (1993). *Observed and Self-reported Seat Belt Wearing as related to Prior Traffic Accidents and Convictions*. Accid. Anal. and Prev., Vol. 25(5):545-554.

265. Hyde, J.S. (1984). *How large are Gender Differences in Aggression?* A developmental meta-analysis. Developmental Psychology, Vol. 20:722-736.

266. Iizuka, H.; Yanagishima, T.; Kataoka, Y.; Seno, T. (1985). *The Development of Drowsiness Warning Devices*. 10th International Technical Conference on Experimental Safety Vehicles, Oxford, U.K.

267. Insurance Research Council.(1991) *Adequacy of Motor Vehicle Records in Evaluating Driver Performance*. Oak Brook, IL:

268. Isherwood, J.; Adam, K.S.; Hornblower, A.R. (1982). *Life Event Stress, Psychological Factors, Suicide Attempt and Auto-accident Proclivity*. Journal of Psychomatic Research, Vol. 26:371-383.

269. James, L. (1997). *Aggressive Driving and Road Rage: Dealing with Emotionally Impaired Drivers.* Retrieved January 5th, 2000 (http://www.house.gov/transportation/surface/sthearin/ist717/james.htm).

270. James, L. *Data on the Private World of the Driver in Traffic: Affective, Cognitive and Sensorimotor*.

271. James, L. *The Nine Zones of your Driving Personality*.

272. James. L. (1997). *Traffic Psychology and the University of Hawaii*.

273. Janis, I.L.; Feshbach, S. (1953). *Effects of Fear-arousing Coomunications*. J. Abnorm. Soc. Psycho., Vol. 48:78-92.

274. Janke, M.K. (1991). *Accidents, Mileage and the Exaggeration of Risk*. Accid. Anal. and Prev., Vol. 23:183-188.

275. Janssen, W.H. (1986). *Modellen vn de Verkeerstaak: De 'State-of-the-art' in 1986*. Institute for Perception Research Report IZF1968C-7, Soesterberg, The Netherlands.

276. Janssen, W.H. (1990). *The Economy of Risk; or, what do I get for my Error?* Ergonomics, Vol. 33(10/11):1333-1348.

277. Janssen, W.H.; Tenkink, E. (1988). *Risk Homeostasis Theory and its Critics: Time for an Agreement*. Ergonomics 31:429-433.

278. Janssen, W.H.; Wierda, M.; Van der Horst, A.R.A. (1992). *Automatisering van de Rijtaak en Gebruikersgedrag: Een Inventatisatie en Research Agenda (Automation of Driving and User Behaviour*. Report TNO-IZF 1992 C-16. Soesterberg, The Netherlands: TNO-TM.

279. Janz, N.K.; Becker, M.H. (1984). *The Health Belief Model: A Decade later*. Health Edu., Vol. 11:1-47.

280. Jenkins, C.D. (1976). *Recent Evidence supporting Psychologic and Social Risk Factors for Coronary Disease*. New England Journal of Medicine, Vol. 294:1033-1038.

281. Jessor, R. (1986). *Risky Driving and Adolescent Problem Behaviour: An Estension of Problem-behaviour Theory*. Alcohol, Drugs and Driving, Vol. 3:1-11.

282. Johansson, G.; Backlund, F. (1970). *Drivers and Road Signs*. Ergonomics 13:749-759.

283. Johansson, G.; Rumar, K. (1966). *Drivers and Road Signs: A Preliminary Investigation of the Capacity of Car Drivers to get Information from Road Signs*. Ergonomics 9:57-62.

284. Johansson, G.; Rumar, K. (1971). *Driver's Brake Reaction Times*. Human Factors, Vol.13, No. 1:23-27.

285. Johansson, R. (1982). *Relation between Subjective and Objective Accident Risk*. TFD Report. Stockholm, Sweden.

286. Johnson, C.A.; Leibowitz, H.W. (1975). *Practice Effects for Visual Resolution in the Periphery*. Perception and Psychophysics, Vol. 25:439-442.

287. Johnson, P.; Klein, T.M.; Levy, P.; Maxwell, D. (1980). *The Effectiveness of the 55 mph National Maximum Speed Limit as a Life Saving Benefit*.National Highway Traffic Safety Administration, Washington, D.C.

288. Johnston, I.R.; Perry, D.R. (1980). *Driver Behaviour Research needs and Priorities*. Research Report ARR 108, Victoria, Australia.

289. Johnston, W.A.; Dark, V.J. (1986). *Selective Attention*. Annu. Rev. Psychol. 37:43-75.

290. Joly, R.; Wilde, G.J.S. (1986). *The Effect of BAC at 0.08% by Volume upon Skill and Risk-taking in a Response-timing Task*. Proceedings at 10th International Conference onAlcohol, Drugs and Traffic Safety, Amsterdam.

291. Jonah, B. (1986). *Accident Risk and Rick-taking Behaviour among Young Drivers*. Accid. Anal. and Prev., Vol. 18(4):255-271.

292. Jonah, B.A. (1997). *Sensation Seeking and Risky Driving: A Review and Synthesis of the Literature*. Accid. Anal. and Prev., Vol. 29(5):651-665.

293. Jones, E.E.; Nisbett, R.E. (1972). *The Acotr and the Observer: Divergent Perceptions of the Causes of Behaviour*. In: E.E. Jones, Ed., Attribution: Perceiving the Causes of Behaviour. General Learning Press, Morristown, NJ.

294. Jones, R.K.; Joksch, H.C.; Lacey, J.H.; Schmidt, H.J. (1988). *Field Evaluation of Jail Sanctions for DWI*. National Highway Safety Administration, DOT HS 807 325, Washington, D.C.

295. Jorgensen, N.O. (1988). *Risky Behaviour at Traffic Signals: A Traffic Engineer's View*. Ergonomics, Vol. 31:657-661.

296. Jorgenson, D.O.; Dukes, F.O. (1976). *Deindividuation as a Function of Density and Group Membership*. J of Personality and Social Psychology, Vol. 34:24-29.

297. Joubert, P. (1985). *Comment*. In: L. Evans, R.C. Schwing, Eds., Human Behavior and Traffic Safety, Plenum Press, New York.

298. Kahneman, D.; Ben-Ishai, R.; Lotan, (1973) M. *Relation of a Test of Attention to Road Accidents*. J. Appl. Psychol. 58:113-115.

299. Kahneman, D.; Slovic, P.; Tversky, A. (1982). *Judgment under Uncertainty: Heuristics and Biases*. New York.

300. Kahneman, D.; Treisman, A. (1984). *Changing Views of Attention and Automaticity.* In: R. Parasuraman, D.R. Davies, Eds., Varieties of attention. Orlando, FL: Academic Press.

301. Kahneman, D.; Tversky, A. (1986). *Choices, Values and Frames*. In: N.J. Smelser, D.R. Gerstein, Eds., Behavioral and Social Science, Fifty Years of Discovery, Washington, D.C.

302. Kaluger, N.A.; Smith, G.L. (Jr.) (1970) *Driver Eye-movement Patterns under Conditions of Prolonged Driving and Sleep Deprivation*. Highway Research Record.

303. Kanowitz, B.H. (1997). *In-vehicle Information Systems: Premises, Promises, and Pitfalls.* Transportation Research Board Conference on Intelligent Transport Systems, Highway Safety and Human Factors, Washington.

304. Katila, A.; Keskinen, E.; Hatakka, M. (1996). *Conflicting Goals of Skid Training*. Accid. Anal. and Prev., Vol. 28(6):785-789.

305. Keinan, G. (1987). *Decision Making under Stress: Scanning of Alternatives under Controllable and Uncontrollable Threats*. Journal of Personality and Social Psychology, Vol. 52:639-644.

306. Kendrick, D.T.; MacFarlane, S.W. (1986). *Ambient Temperature and Horn-honking: A Field Study of the Heat/Aggression Relationship*. Environment and Behaviour, Vol. 18(22):179-191.

307. Kenny, D.A.(1979). *Correlation and Causality*. New York.

308. Keskinen, E. (1994). *Why Young Drivers have more Accidents*. First Interdisciplinary Conference on Young Drivers, Vol. 12:12-14. Cologne, Germany.

309. Keskinen, E.; Hatakka, M.; Katila, A.; Laapotti, S. (1992). *Was the Renewal of the Driver Training Successful*? Psychological Reports, No. 94, University of Turku.

310. Kimball, K.A.; Ellingstad, V.S.; Hagen, R.E. (1971). *Effects of experience on Patterns of Driving Skill*. J. Safety Research, Vol. 3(3):129-135.

311. Kimura, I. (1993). *The Relationship between Drivers' Attitude toward Speeding and their Speeding Behaviour in Hypothetical Situations*. Hiroshima Forum for Psychology.

312. King, K.W.; Reid, L.N. (1990). *Fear Arousing Anti-drinking and driving PSA's: Do Physical Injury influence Young Adults*. Curr. Issue Res. Advert., Vol. 13:155-157.

313. Kishida, K. (1973). *Temporal Changes of Subsidiary Behavior in Monotonous Work*. Journal of Human Ergology, Vol. 2:75-89.

314. Kjellén, U. (1987). *Deviations and the Feedback Control of Accidents*. In: J. Rasmussen, K. Duncan, J. Leplat, Eds., New Technology and Human Error, pp.143-156. Wiley, Chichester.

315. Klayman, N.; Ha, Y-W. (1987). *Confirmation, Disconfirmation and Information in Hypothesis Testing*. Psychological Review, Vol. 94:211-228.

316. Klein, J.D.; Brown, J.D.; Childers, K.W.; Oliveri, J.; Porter, C.; Dykers, C. (1993). *Adolescents' Risky Behavior and Mass Media Use*. Pediatrics, Vol. 92(1).

317. Knapp, R.K.; Vardaman, J.J. (1991). *Response to an Automated Function Failure Cue: An Operational Measure of Complacency*. Proceedings of the Human Factors Society 35th annual meeting, pp.112-115. HFES:Santa Monica, CA, USA.

318. Knapper, C.K.; Cropley, A.J. (1978). *Towards a Social Psychology of the Traffic Environment*. In: D.F. Burkhardt, W.H. Ittelson, Eds., Environmental Assessment of Socio-economic Systems. Plenum, New York.

319. Kohn, P.M.; Goodstadt, M.G.; Cook, G.M.; Sheppard, M.; Chan, G. (1982). *Ineffectiveness of Threat Appeals about Drinking and Driving*. Accid. Anal. and Prev., Vol. 14:457-464.

320. Koriat, A.; Hasida,B-Z. (1988). *Remembering that I did it: Processes and Deficits in Output Monitoring*. In: M.M. Gruneberg, P.E. Morris, R.N. Sykes, Eds., Practical Aspects of Memory: Current Research and Issues, Vol. 1. Wiley, Chichester.

321. Koshi, M. (1985). *Road Safety Measures in Japan*. In: L. Evans, R.C. Schwing, Eds., Human Behavior and Traffic Safety. Plenum Press, New York.

322. Kraiss, K.F.; Küttelwesch, H. (1992). *Identification and Application of Neural Operator Models in a Car Driving Situation*. IFAC Man-Machine Symposium. Preprints 2.2.1.

323. Krewski, D.; Somers, E.; Birkwood, P.L. (1987). *Risk Perception in a Decision Making Context*. Journal of Environmental Science and Health, Part C5(2):175-209. Marcel Dekker Inc.

324. Kuhl, J.; Kazen-Saad, M. (1988). *A Motivational Approach to Volition: Activation and Deactivation of Memory Representations related to Uncompleted Intentions*. In: V. Hamilton, G.H. Bower, N.H. Frijda, Eds., Cognitive Perspectives on Emotion and Motivation, pp.63-85. Kluwer Academic, Dordrecht.

325. Kuhn, T.S. (1962). *The Structure of Scientific Revolutions*. Chicago, IL: University of Chicago Press.

326. Kunreuther, H. (1985). *Incentives for Improving Driving Behaviour: Ex ante/ex post Considerations*. In: L.Evans, R.C.Schwing, Eds., Human Behaviour and Traffic Safety, pp.365-378. Plenum Press, New York.

327. Kunreuther, H.; Ginsberg, R.; Miller, L.; Sagi, P.; Slovic, P.; Borkin, B.; Katz, N. (1978). *Disaster Insurance Protection: Public Policy Lessons*. Wiley-Interscience, New York.

328. Laberge-Nadeau, C.; Maag, U.; Bourbeau, K. (1992). *The Effects of Age and Experience on Accident with Injuries: Should the Licencing Age be raised?* Accid. Anal. and Prev., Vol. 24:107-116.

329. Laird, J.; Newell, A.; Rosenbloom, P. (1987). *SOAR: An Architecture for General Intelligence*. Artificial Intelligence, Vol. 33:1-64.

330. Lajunen, T.; Summala, H. (1995). *Driving Experience, Personality, and Skill and Safety-motive Dimensions in Drivers' Self-assessments*. Personality and Individual Differences, Vol. 19:307-318.

331. Lajunen, T.; Summala, H. (1996). *Effects of Driving Experience, Personality,Driver's Skill and Safety Orientation of Speed Regulation and Accidents.* International Conference on Traffic and Transport Psychology, Valencia, Spain.

332. Lamble, D.; Kauranen, T.; Laakso, M.; Summala, H. (1999). *Cognitive Load and Detection Thresholds in Car Following Situations: Safety Implications for Using Mobile (Cellular) Telephones while Driving*. Accid. Anal. and Pre., Vol. 31:617-623.

333. Lamble, D.E.; Laakso, M.; Summala, H. (1996). *The Effects of Driving Experience on Drivers' Ability to detect Braking and Decelerating of a Lead Vehicle using Peripheral Vision*. International Conference on Traffic and Transport Psychology, Valencia.

334. Land, M.F.; Lee, D.N. (1994). *Where We Look when We Steer*. Nature, Vol. 369:742-743.

335. Laurell, H.; Lisper, H.-O. (1978). *A Validation of Subsidiary Reaction Time against Detection of Roadside Obstacles during Prolonged Driving*. Ergonomics, Vol. 21(2):81-88.

336. Lawton, R.; Parker, D.; Manstead, A.S.R.; Stradling, S.G. (1997). *The Role of Affect in Predicting Social Behaviors: The Case of Road Traffic Violations.* Journal of Applied Social Psychology, Vol. 27:1258-1276.

337. Lazarus, R.S. (1993). *From Psychological Stress to the Emotions: A History of Changing Outlooks*. Annual Review of Psychology, Vol. 44:1-21.

338. Lazarus, R.S.; Deese, J.; Osler, S.F. (1952). *The Effects of Psychological Stress upong Performance*. Psychological Bulletin, Vol. 49:293-317.

339. Lazarus, R.S.; Folkman, S. (1984). *Stress, Appraisal and Coping*. Springer, New York.

340. Lehto, M.R. (1991). *A Proposed Conceptual Model of Human Behavior and its Implications for Design of Warnings*. Percept. Mot. Skills 73:595-611.

341. Leibowitz, H.W. (1986). *Recent Advances in our Understanding of Peripheral Vision and some Implications*. Proceedings of the Human Factors Society, 30th Annual Meeting, pp.605-607.

342. Leonard, S.D. (1997). *What You don't know can hurt you: II. Automobile Operations*. In: Proceedings of the 13th Trennial Congress of the International Ergonomics Association. Finnish Institute of Occupational Health, Helsinki.

343. Leonard, S.D.; Karnes, E.W. (1998). *Perception of Risk in Automobiles: Is it Accurate?* Proceedings of the Human Factors and Ergonomics Society 42nd Annual Meeting.

344. Leventhal, H.; Singer, R.P.; Jones, S. (1965). *The Effects of Fear and Specificity of Recommendations*. J. Personal. Soc. Psychol., Vol. 2:20-29.

345. Lewin, I. (1982). *Driver Training: A Perceptual-motor Skill Approach*. Ergonomics, Vol. 25:917-924.

346. Lichtenstein, S.; Slovic, P.; Fischhoff, B.; Layman, M.; Combs, B. (1978). *Judged Frequency of Lethal* Events. Journal of Experimental Psychology: Human Learning and Memory, Vol. 4:551-578.

347. Liikenneturva, (1997). *One Driver in Three Uses a Mobile Phone while Driving*. The Central Office for Traffic Safety in Finland.

348. Limbourg, M.; Gerber, D. (1981). *A Parent Training Program for the Road Safety Education of Preschool Children.* Accident Analysis and Prevention, Vol. 13:255-267.

349. Lindholm, E.; Cheatham, C.M. (1983). *Automatic Activity and Workload during Learning of a Simulated Aircraft Carrier Landing Task.* Aviation Space and Environment Medicine, Vol. 54:435-439.

350. Lindzey, G.; Aronson, E. (1985) *The Handbook of Social Psychology*. New York

351. Linfield, P.B.; Dunne, M.C.M. (1988). *The Effects of Alcohol Induced Binocular Instability on a Driver's Ability to Correctly Identify Road Direction Signs.* In: Proc., Second Conference on Vision in Vehicles, pp. 75-82. Amsterdam, North Holland.
352. Lisper, H.-O.; Dureman, I.; Ericsson, S.; Karlsson, N.G. (1971). *Effects of Sleep Deprivation and Prolonged Driving on a Subsidiary Auditory Reaction Time*. Accid. Anal. and Prev., Vol. 2:335-341.
353. Lisper, H.-O.; Laurell, H.; Van Loon, J. (1974). *Relationen Mellan Uthållighet (tid till insomnande) och Ökningen av Auditiv Reaktionstid.* Psykologiska institutionen, Uppsala Universitet.
354. Liu, J.Y.; Mooney, D.P.; Meyer, M.M.; Shorter, N.A. (1998). *Teenage Driving Fatalities.* Journal of Pediatric Surgery, Vol. 33(7):1084-1088.
355. Loftus, G.R.; Mackworth, N.H. (1978). *Cognitive Determinants of Fixation Location during Picture Viewing.* Journal of Experimental Psychology: Human Perception and Performance, Vol. 4:565-572.
356. Lourens, P.F. (1990). *Theoretical Perspectives on Error Analysis and Traffic Behaviour.* Ergonomics, Vol. 33(10/11): 1251-1263.
357. Lowenstein L.F. (1997). *Research into Causes and Manifestations of Aggression in Car Driving*. Police Journal 70:263-270.
358. Luria, A.R. (1966). *Higher Cortical Functions in Man*. Tavistock, London.
359. Lynch, K.; Rivkin, M. (1959). *A Walk around the Block*. Landscape, Vol.8:24-34.
360. Macdonald, W.A.; Hoffmann, E.R. (1984). *Drivers' Awareness of Traffic Sign Information.* Australian Road Research Board Internal Report, AIR 382-1, Melbourne.
361. Mackworth, N.H. (1976). *Stimulus Destiny limits the Useful Field of View.* In: R.A. Monty, J.W. Senders, Eds., Eye Movements and the Higher Psychological Process, pp.307-321. Lawrence Erlbaum, Hillsdale.
362. Malaterre, G.; Ferandez, F.; Fleury, D.; Lechner, D. (1988). *Decision Making in Emergency Situations*. Ergonomics, Vol. 31(4):643-655.
363. Manstead, A.S.R.; Parker, D.; Stradling, S.G.; Reason, J.T.; Baxter, J.S. (1992). *Perceived Consensus in Estimates of the Prevalence of Driving Errors and Violations*. J. Appl. Soc. Psychol. 22:509-530.
364. Marsh, P.; Collett, P. (1986). *Driving Passion: The Psychology of the Car*. Faber and Faber, Boston.
365. Marsh, P.; Collett, P. (1987). *The Car as a Weapon*. Etc. Sum. Vol. 44(2):146-151.
366. Martin, M. (1985). *Neuroticism as Predisposition towards Depression: A Cognitive Mechanism*. Personality and Individual Differences, Vol. 6:353-365.McCrae, R.R.; Costa,

P.T. (1986). *Personality, Coping and Coping Effectiveness in an Adult Sample*. Journal of Personality, Vol. 54:385-405.

367. Martinez, R. (1997). *Statement of the Honorable Ricardo Martinez, M.D., Administrator, National Highway Traffic Safety Administration,* before the U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Surface Transportation, Washington, DC, July 17.
368. Matthews, G.; Desmond, P.A. (1995). *Stress as a Factor in the Design of In-car Driving Enhancement Systems*. Le Travail Humain, Vol. 58:109-129.
369. Matthews, G.; Dorn, L.; Glendon, A.I. (1991). *Personality Correlates of Driver Stress*. Person. Indiv. Diff., Vol. 12(6):535-549. Pergamon Press, Great Britain.
370. Matthews, M.L.; Moran, A.R. (1986). *Age Differences in Male Drivers' Perception of Accident Risk: The Role of Perceived Driving Ability*. Accid. Anal. and Prev., Vol. 18(4):299-313.
371. Maycock, G.; Lester, J.; Lockwood, C.R. (1996). *The Accident Liability of Car Drivers: The Reliability of Self-Reported Data.* TRL Report 219, Transport Research Laboratory, Crowthorne, UK.
372. Maycock, G.; Lockwood, C.R.; Lester, J.F. (1991). *The Accident Liability of Car Drivers*. Transport and Road Research Laboratory, Crowthorne, U.K.
373. McCarthy, P.S. (1986). *Seat Belt Usage Rates: A Test of Peltzman's Hypothesis*. Accid. Anal. and Prev., Vol. 18(5):425-438.
374. McCloskey, M.; Caramazza, A.; Green, G. (1980). *Curvilinear Motion in the Absence of Esternal Forces: Naïve Beliefs about the Motion of Objects*. Science, Vol. 210:1139-1141.
375. McCloskey, M.; Washburn, A.; Felch, L. (1983). *Intuitive Physics: The Straight Down Belief and its Origin*. J of Experimental Psychology: Learning, Memory and Cognition Vol. 9:636-649.
376. McClumpha, A.J.; James, M.; Green, R.G.; Belyavin, A.J. (1991). *Pilot's Attitudes to Cockpit Automation*. Proceedings of the Human Factors Society 35th annual meeting, pp.107-111. HFES:Santa Monica, CA, USA.
377. McDonald, P.J.; Wooten, S.A. (1988). *The Influence of Incompatible Responses on the Reduction of Aggression: An Alternative Explanation*. J of Social Psychology, Vol. 128:401-406.
378. McGarva, A.R.; Steiner, M. (2000). *Provoked Driver Aggression and Status: a Field Study.* Transportation Research Part F3, pp. 167-179.
379. McGuire, W.J. (1985). *Attitudes and Attitude Change*. In: G. Lindsey, E. Aronson, Eds., The Handbook of Social Psychology, pp.233-246. Random House, New York.

380. McKeller, P. (1965). *The Investigation of Mental Images*. Penguin Science Survey (Biological Sciences), Harmonsworth.

381. McKenna, F.P. (1982). *The Human Factor in Driving Accidents: An Overview of Approaches and Problems*. Ergonomics 25:867-877.

382. McKenna, F.P. (1988). *What Role should the Concept of Risk play in Theories of Accident Involvement?* Ergonomics, Vol. 31(4):469-484.

383. McKenna, F.P.; Duncan, J.; Brown, I.D. (1986). *Cognitive Abilities and Safety on the Road: A Re-examination of Individual Differences in Dichotic Listening and Search for Embedded Figures*. Ergonomics, Vol. 29(5):649-663.

384. McLean, J.R.; Hoffman, E.R. (1971). *Analysis of Drivers' Control Movements*. Human Factors, Vol. 13:407-418.

385. Mercer, G.W.; Wayne, J.K. (1995). *Patterns of Convictions and Traffic Accident Involvement*. Criminal Behaviour and Mental Health, Vol. 5:463-478.

386. Messick, D.; Brewer, M. (1983). *Solving Social Dilemmas*. In: L. Wheeler, P. Shaver, Eds., Review of Personality and Social Psychology, Vol. 4. Beverly Hills, CA.

387. Michiels, W.; Schneider, P.A. (1984). *Traffic Offenses: Another Approach to Description and Prediction*. Accid. Anal. and Prev., Vol. 16:223-238.

388. Michon, J.A. (1971). *Psychonomie onderweg*. Inaugural lecture, University of Groningen. Wolters Noordhoff, Groningen.

389. Michon, J.A. (1976). *The Mutual Impacts of Transportation and Human Behavior*. In: P. Stringer, H. Wentzel, Eds., Transportation Planning for a better Environment, Pp.221-236. Plenum Press, New York.

390. Michon, J.A. (1978). *Dealing with Danger*. Traffic Research Centre Report VK79-01, University of Groningen.

391. Michon, J.A. (1984). *Traffic and Mobility*. In: P.J.D. Drenth, H. Thierry, P.J. Willems, C.J. de Wolff, Eds., Handbook of work and organizational psychology, Vol. 2. Wiley, London.

392. Michon, J.A. (1985). *A Critical View of Driver Behaviour Models. What do we know, what should we do?* In: L. Evans, R. Schwing, Eds., Human behavior and traffic safety. NewYork: Plenum Press.

393. Michon, J.A. (1989). *Explanatory Pitfalls and Rule-based Driver Models*. Accid. Anal. Prev., Vol. 21:341-353.

394. Michon, J.A. (1993). *Generic Intelligent Driver Support*. Taylor and Francis, London.

395. Michon, J.A.; Smiley, A.; Aasman, J. (1990). *Errors and Driver Support Systems*. Ergonomics, Vol. 33:1215-1229.

396. Mihal, W.L.; Barrett, B.V. (1976). *Individual Differences in Perceptual Information Processing and their Relation to Automobile Accident Involvement*. J. Appl. Psychol. 61:229-233.
397. Miller, G.A.; Galanter, E.; Pribram, K.H. (1960). *Plans and the Structure of Behaviour*. Holt, Rinehart and Winston, New York.
398. Miller, T.R.; Spiner, R.S.; Lestina, D.C. (1998). *Who is Driving when Unrestrained Children and Teenagers are hurt*? Accid. Anal. and Prev., Vol. 30(6):839-849.
399. Minter, A.L. (1987). *Road Casualties – Improvement by Learning Processes.* Traffic Engineering and Control, Vol. 28:74-79.
400. Mitterauer, M. (1991). *Ungdomstidens Sociala Historia (The Social History of Youth)*. Röda Bokförlaget, Göteborg.
401. Miura, T. (1990). *Active Function of Eye Movement and Useful Field of View in a Realistic Setting*. In: R. Groner, G. d'Ydewalle, Eds., From Eye to Mind: Information Acquisition in Perception, pp.119-127. Elsevier, Amsterdam.
402. Moe, D.; Jenssen, G.D. (1990). *Unge Forere, Risikotaking og Pedagogiske Konsekvenser. (Young Drivers, Risktaking and Pedagogical Consequences)*. SINTEF Transport Engineering, Trondheim, Norway.
403. Moe, D.; Jenssen, G.D. (1993). *Ungdom, Risikotaking og bilkjoring (Young Drivers, Risk Taking and Traffic Accidents)*. SINTEF Transport Engineering Trondheim, Norway.
404. Molloy, R.; Parasuraman, R. (1996). *Monitoring an Automated System for Single Failure: Vigilance and Task Complexity Effects*. Human Factors, 38:311-322.
405. Moraal, J. (1980). *De Studie van het Verkeersgedrag*. Ergonomics, Vol. 5:1-8.
406. Moray, N. (1981). *The Role of Attention in the Detection of Errors and the Diagnosis of Failures in Man-machine Systems*. In: J. Rasmussen, W.B. Rouse, Eds., Human Detection and Diagnosis of System Failures. Plenum, New York.
407. Moray, N. (1987). *Monitoring Behaviour and Supervisory Control*. In: K. Boff, L. Kaufman, J. Thomas, Eds., Handbook of Perception and Human Performance. Wiley, New York.
408. Moray, N. (1990). *Designing for Transportation Safety in the Light of Perception, Attention and Mental Models*. Ergonomics, Vol. 33(10/11):1201-1213.
409. Moray, N.; Rotenberg, I. (1989). *Fault Management in Process Control: eye Movements and Action*. Ergonomics, Vol. 32:1319-1342.
410. Mortimer, R.G. (1990). *Perceptual Factors in Rear-end Crashes*. Human Factors Soc. 34th Annual Meeting, pp.591-594. Orlando.
411. Mourant, R.R.; Rockwell, T.H. (1972). *Strategies of Visual Search by Novice and Experienced Drivers.* Human factors, Vol. 14:325-335.

412. Näätänen, R.; Summala, H. (1974). *A Model for the Role of Motivational Factors in Drivers' Decision Making*. Accid. Anal. and Prev., Vol. 6:243-261.

413. Näätänen, R.; Summala, H. (1976). *Road User Behaviour and Traffic Accidents*. New York: North Holland Publishing Company.

414. Neisser, U. (1963). *The Imitation of Man by Machine*. Science, Vol. 139:193-197.

415. Neisser, U. (1976). *Cognition and Reality: Principles and Implications of Cognitive Psychology*. San Francisco, CA: W.H. Freeman and Company.

416. Niehaus, A.; Stengel, R.F. (1991). *An Expert System for Automated Highway Driving*. IEEE Control Systems Magazine, Vol. 11(3):53-61.

417. Nilsson, E.; Åberg, L. (1986). *Övervakning och påföljd*. Transportforskningsberedningen, (TFB-rapport 11).

418. Norman, D.A. (1980). *Post-Freudian Slips*. Psychology Today, pp.42-50.

419. Norman, D.A. (1981). *Categorization of Action Slips*. Psychological Review, Vol. 1:1-15.

420. Norman, D.A.; Bobrow, D.G. (1975) *On Data-limited and Resource-limited Processes*. Cognitive Psychology 7:44-64.

421. Noy, Y.I. (1997). *Human Factors in Modern Traffic Systems.* Ergonomics, Vol. 40 (10):1016-1024.

422. OECD (1975). *Young Driver Accidents*. Organization for Economic Co-operation and Development, Paris.

423. OECD. *Research on Traffic Law Enforcement: Effects of Enforcement of Legislation on Road User Behaviour and Traffic Accidents*. Organization for Economic Cooperation and Development, Paris.

424. Olson, P.L. (1974). *Aspects of Driving Performance as a Function of Field Dependence*. Journal of Applied Psychology, Vol. 59:192-196.

425. Olson, P.L.; Wachsler, R.A.; Bauer, H.J. (1961). *Driver Judgments of Relative Car Velocity*. J. Appl. Psychol., Vol. 45:161-164.

426. Onken, R.; Feraric, J.P. (1997). *Adaptation to the Driver as Part of a Driver Monitoring and Warning System.* Accid. Anal. and Prev., Vol. 29(4):507-513.

427. Oppe, S. (1988). *The Concept of Risk: A Decision Theoretic Approach*. Ergonomics, Vol. 31(4):435-440.

428. Ostvik, E. (1989). *Radarkontroll og Fartsvalg.*Transportokonomisk Institutt. (Arbeidsdokument av 1989, Prosjekt 0-1385).

429. Ota, H. (1994). *Distance Headway Behavior between Vehicles from the Viewpoint of Proxemics*. IATSS Research, Vol. 18:6-14.

430. Owsley, C.; Ball, K.; Sloane, M.; Roenker, D.L.; Bruni, J.R. (1991). *Visual/Cognitive Correlates of Vehicle Accidents in Older Drivers*. Psychol Aging, Vol. 6:403-415.

431. Oza, N.C. (1998). *Probabilistic Models of Driver Behavior*. Master of Science Research Project, University of California, Berkeley, California.

432. Paivio, A. (1971). *Dual Coding Theory*. Holt, Reinhardt and Winston, New York.

433. Palfai, T.P.; Salovey, P. (1992). *The Influence of Affect on Self-focused Attention: Conceptual and Methodological Issues*. Consciousness and Cognition, Vol. 1:306-339.

434. Panek, P.E.; Barrett, G.V.; Sterns, H.L.; Alexander, R.A. (1977). *A Review of Age Changes in Perceptual Information Processing Ability with Regard to Driving*. Exp. Aging Res. 3:387-449.

435. Papacostas, C.S.; Prevedouros, P.D. (1993). *Transportation Engineering and Planning*. Prentice-Hall, NJ.

436. Papelis, Y.; Ahmad, O. (2001). *A Comprehensive Microscopic Autonomous Driver Model for Use in High-Fidelity Driving Simulation Environments*. Transportation Research Board 80th Annual Meeting, Washington, D.C., Paper No. 01-3418.

437. Parasuraman, R.; Nestor, P.G. (1991). *Attention and Driving Skills in Aging and Alzheimer's Disease*. Human Factors, Vol. 33:539-557.

438. Parducci, A. (1978) *Contextual Effects: A Range-frequency Analysis*. Handbook of Perception, New York.

439. Parker, D.; Manstead, A.S.R.; Stradling, S.G.; Reason, J.T. (1992). *Determinants of Intention to commit Driving Violations*. Accid. Anal. and Prev., Vol. 24:117-131.

440. Parker, D.; Manstead, A.S.R.; Stradling, S.G.; Reason, J.T.; Baxter, J.S. (1992). *Intention to commit Driving Violations: An Application of the Theory of Planned Behaviour*. J. Appl. Psychol. 77:94-101.

441. Parker, D.; Reason, J.T.; Manstead, A.S.R.; Strandling, S.G. (1995). *Driving errors, driving violations and accident involvement*. Ergonomics, Vol. 38:1036-1048.

442. Parsons, H.M. (1979). *Behaviour Analysis in Highway Safety*. Invited address at the Annual Meeting of the Association for Behavior Analysis, Dearborn, Michigan, U.S.A.

443. Pennebacker, J.W. (1989). *Stream of Consciousness and Stress: Levels of Thinking*. In: J.S. Uleman, J.A. Bargh, Eds., Unintended Thought: Limits of Awareness, Intention and Control, pp.327-350. Guilford Press, New York.

444. Perry, A.R. (1986). *Type A Behavior Pattern and Motor Vehicle Drivers' Behavior*. Perceptual and Motor Skills, Vol. 63:875-878.

445. Persson, H.; Towliat, M.; Almqvist, S.; Risser, R.; Magdeburg, M. (1993). *Speed Limiters for Cars. A Field Study of Driving Speeds, Driver Behaviour, Traffic Conflicts and Comments by*

Drivers in Town and City Traffic. Department of Traffic Planning and Engineering, University of Lund, Sweden.

446. Peterson, C.; Maier, S.F.; Seligman, M.E.P. (1993). *Learned Helplessness: A Theory for the Age of Personal Control*. Oxford University Press, New York.
447. Phillipps-Bertin, C.; Khardi, S.; Olivier, D.; Rogè, J. (1994). *Vigilance-aide à la Conduite Automobile, Role de L'activitè Cognitive dans le Maintien de la Vigilance du Conducteur Automobile*. Report No. 9431, INRETS, Lyon.
448. Piersma, E.H. (1993). *Adaptive Interfaces and Support Systems in Future Vehicles*. In: A.M. Parkes, S. Franzen, Eds., Driving Future Vehicles, pp.321-332. Taylor and Francis, London.
449. Pittman, T.S.; D'Agostino, P.R. (1989). *Motivation and Cognition: Control Deprivation and the Nature of the Subsequent Information Processing*. Journal of Experimental Social Psychology, Vol. 25:465-480.
450. Planek, T.W.; Fowler, R.C. (1971). *Traffic Accident Problems and Exposure Characteristics of the Aging Driver*. J. Gerontol. 26:224-230.
451. Plude, D.; Hoyer, W. (1988). *Attention and Performance: Identifying and Localizing Age Deficits*. In: N. Charness, Ed., Aging and Human Performance, pp.47-99. Wiley, New York.
452. Poser, C.-M. (1993). *Automobile Driving Fitness and Neurological Impairment.* Journal of Neuropsychiatry and Clinical Neurosciences, Vol. 5.
453. Poulton, E.C. *Speed Acticipation and Course Anticipation inTracking*. Med. Res. Council, APU123/50, ATI 127136, Cambridge, England.
454. Prentice-Dunn, S.; Rogers, R.W. (1980). *Effects of Deindividuation Situational Cues and Aggressive Models onSubjective Deindividuation and Aggression*. J of Personality and Social Psychology, Vol. 39:104-113.
455. Preusser, D.F.; Blomberg, R.D. (1987). *Development and Validation of a Road Safety Public Education Process.* In: J.A. Rothengatter; R.A. De Bruin, Eds., Road Users and Traffic Safety. Van Gorcum, Assen.
456. Preusser, D.F.; Williams, A.F.; Lund, A.K. (1991). *Characteristics of Belted and Unbelted Drivers*. Accid. Anal. and Prev., Vol. 23(6):475-482.
457. Quenault, S.W. (1967). *Driver Behaviour: Safe and Unsafe Drivers*. Road Research Laboratory Report LR70, Crowthorne.
458. Quenault, S.W. (1968a). *Driver Behaviour: Safe and Unsafe Drivers II*. Road Research Laboratory Report LR146, Crowthorne.
459. Quenault, S.W. (1968b). *Dissociation and Driver Behaviour*. Road Research Laboratory Report LR212, Crowthorne.

460. Quenault, S.W.; Parker, P.M. (1973). *Driver Behaviour: Newly-qualified Drivers*. Transport and Road Research Laboratory Report LR567, Crowthorne.

461. Quimby, A.R.; Watts, G.R. (1982). *Human Factors and Driving Performance*. Report No. 1004. Transport and Road Research Laboratory, Crowthorne, Berkshire, England.

462. Rabbitt, P. (1990). *Age, IQ and Awareness, and Recall of Errors*. Ergonomics, Vol. 33(10/11):1291-1305.

463. Rabbitt, P.M.A. (1981). *Cognitive Psychology needs Models for Changes in Performance with Old Age.* In: J. Long, A Baddeley, Eds., Attention and Performance IX. Hillsdale, NJ: Lawrence Erlbaum Associates.

464. Rabbitt, P.M.A. (1982). *How do Older People know what to do next?* In: F.I.M. Craik, S. Trehub, Eds., Aging and cognitive processes. New York: Plenum Press.

465. Rajalin, S.; Hassel, S-O.; Summala, H. (1997). *Close-following Drivers on Two-lane Highways*. Accid. Anal. and Prev., Vol. 29(6):723-729.

466. Ranney, T.A. (1994). *Models of Driving Behavior: A Review of Their Evolution*. Accid. Anal. and Prev., Vol. 26:733-750.

467. Rasmussen, J. (1980). *What can be learned from Human Error Reports*? In: K.D. Duncan, M. Gruneberg, D. Wallis, Eds., Changes if Working Life. Wiley, London.

468. Rasmussen, J. (1983). *Skills, Rules, and Knowledge: Signals, Signs, and Symbols, and other Distinctions in Human Performance*. Models. IEEE Transactions on Systems, Man, and Cybernetics, 13:257-266.

469. Rasmussen, J. (1986). *Information Processing and Human-Machine Interaction*. North-Holland, Amsterdam.

470. Rasmussen, J. (1987). *The Definition Human Error and a Taxonomy for Technical System Design*. In: J. Rasmussen, K. Duncan, J. Leplat, Eds., New technology and human error. Chichester, U.K.: Wiley.

471. Rasmussen, J. (1990). *The Role of Error in Organizing Behaviour.* Ergonomics, Vol. 33 (10/11):1185-1199.

472. Reason, J.T. (1976). *Absent Minds.* New Society, Vol. 4:244-245.

473. Reason, J.T. (1979). *Actions not as Planned: The Price of Automatization*. In: G. Underwood, R. Stevens, Eds., Aspects of Consciousness, pp.67-89. Academic, London.

474. Reason, J.T. (1990a). *Human Error*. Cambridge: Cambridge University Press.

475. Reason, J.T.; Manstead, A.S.; Stradling, S.G.; Baxter, J.S.; Campbell, K.A. (1990b). *Errors and Violations on the Road: A real Distinction*. Ergonomics, Vol. 33:1315-1333.

476. Reason, J.T.; Shotton, R.; Wagenaar, W.A.; Hudson, P.T.; Groeneweg, J. (1988). *TRIPOD: A Principal Basis for Safer Operations*. Report Leiden University/University of Manchester, prepared for Shell International.
477. Rehm, J.; Steinleitner, M.; Lilli, W. (1987). *Wearing Uniforms and Aggression: A Field Experiment*. European Journal of Social Psychology, Vol. 17:357-360.
478. Reitman, W.R. (1965). *Cognition and Thought*. Wiley, New York.
479. Renge, K. (1980). *The Effects of Driving Experience on a Driver's Visual Attention. An Analysis of Objects looked at: Using the 'Verbal Report' Method.* International Association of Traffic Safety Sciences Research, Vol. 4:95-106.
480. Renge, K. (1995). *Effect of Driving Experience on Drivers' Decoding Process of Roadway Interpersonal Communication*. Laboratory of Psychology, Faculty of Liberal Arts, Tezukayama University, Nara, Japan.
481. Retting, R.A.; Williams, A.F. (1996). *Characteristics of Red Light Violators: Results of a Field Investigation.* Journal of Safety Research, Vol. 27:9-15.
482. Richardson, J.H. (1995). *The Development of a Driver Alertness Monitoring Device*. In: L. Hartley, Ed., Fatigue and Driving, pp.219-229, Taylor and Francis, London.
483. Richardson, J.H.; Ward, N.J.; Fairclough, S.H.; Graham, R. (1996). *PROMETHEUS/DRIVE AICC Safety Assessment: Basic Simulator*. HUSAT Research Institute, Loughborough, UK.
484. Riemersma, J.B.J. (1987). *Visual Cues in Straight Road Driving*. Drukkerij Neo Print, Soest, Netherlands.
485. Risser, R. (1990). *Communication and Accident* Risk. In: T. Benjamin, Ed., Driving Behaviour in a Social Context. Proceedings of an International Symposium, Caen: Paradigme.
486. Robertson, L.S. (1996). *Reducing Death on the Road: The Effects of Minimum Safety Standards, Publicised Crash Tests, Seat Belts and Alcohol*. American Journal of Public Health, Vol. 86(1):31-34.
487. Robinson, G.H.; Erickson, D.J.; Thurston, G.L.; Clark, R.L. (1972). *Visual Search by Automobile Drivers*. Human Factors, Vol. 14(4):315-323.
488. Rockwell, T. (1972). *Skills, Judgement and Information Acquisition in Driving*. In: T.W. Forbes, Ed., Human factors in highway traffic safety research. New York: John Wiley & Sons.
489. Rogè, J.; Pebayle, T.; Muzet, A. (2001). *Variations of the Level of Vigilance and of Behavioural Activities during Simulated Automobile Driving*. Accid. Anal. and Prev., Vol. 33:181-186.
490. Rolls, G.W.P.; Hall, R.D.; Ingham, R.; McDonald, H.; (1991). *Accident Risk and Behavioural Patterns of Younger Drivers*. AA Foundation for Road Safety Research, Basingstoke.

491. Roque, G.M.; Roberts, M.C. (1989). *A Replication of the Use of Public Posting in Traffic Speed Control*. J. Appl. Behav. Anal. 22:325-330.

492. Rosengren, L.G. (1995). *Driver Assistance and Co-operative Driving*. In: Ertico, Ed., Towards an intelligent transport system. Proceedings of the First World Congress on Advanced Transport Telematics and Intelligent Vehicle Highway Systems. London: Artech House, pp.1613-1622.

493. Ross, H.L. (1982). *Deterring the Drinking Driver*. Legal policy and social control. Lexington books, Lexington, MA.

494. Ross, L.D. (1977). *The Intuitive Psychologist and his Shortcomings: Distortions in the Attribution Process*. In: L. Berkowitz, Ed., Advances in Experimental Social Psychology, Vol. 10. Academic Press, New York.

495. Ross, L.D.; Amabile, T.M.; Steinmetz, J.L. (1977). *Social Roles, Social Control and Biases in Social Perception Processes*. Journal of Personality and Social Psychology, Vol. 35:485-494.

496. Rothe, P. (1990). *Intersection Crossing Behaviour*. In: T. Benjamin, Ed., Driving Behaviour in a Social Context, Proceedings of an International Symposium. Caen: Paradigme.

497. Rothengatter, J.A. (1984). *The Role of Media in Road Safety Education for Young Children*. British Journal of Developmental Psychology, Vol. 2:157-165.

498. Rothengatter, T. (1988). *Risk and the Absence of Pleasure: A Motivational Approach to Modelling Road User Behaviour*. Ergonomics, Vol. 31(4):599-607.

499. Rothengatter, T. (1988a). *Road User Behavior: Theory and Research*. Assen, The Netherlands: Van Gorcum.

500. Roy, G.S.; Choudhary, R.K. (1985). *Driver Control as a Factor in Road Safety*. Asian J of Psychology and Education, Vol. 16(3):33-37.

501. Rumar, K. (1988). *Collective Risk but Individual Safety*. Ergonomics, Vol. 31(4):507-518.

502. Rumar, K. (1990). *The Basic Driver Error: Late Detection*. Ergonomics, Vol. 33:1281-1290.

503. Rumar, K.; Berggrund, V. (1973). *Overtaking Performance under Controlled Conditions*. First Int. Conf. On Driver Behaviour Research, Zurich.

504. Rylander, R.; Bjorkman, M.; Ahrlin, U.; Arntzen, E.; Solberg, S. (1986). *Dose-response Relationship for Traffic Noise and Annoyance*. Archives of Environmental Health, Vol. 41:7-10.

505. Saarinen, J. (1993). *Focal Attention and the Perception of Pattern Structure in Extrafoveal Vision*. Scandinavian Journal of Psychology, Vol. 34:129-134.

506. Salvatore, S. (1967). *Estimation of Vehicular Velocity under Time Limitation and Restricted Conditions of Observation*. Highway Research Record, Vol. 195:66-74.

507. Salvucci, D.D.; Boer, R.B.; Liu, A. (2001). *Toward an Integrated Model of Driver Behaviour in a Cognitive Architecture.* Transportation Research Board 80th Annual Meeting, Washington, D.C.

508. Sanders, A.F. (1970). *Some Aspects of the Selective Process in the Functional Field of View.* Ergonomics, Vol.13:117.

509. Schneider, W. (1985). *Training High-performance Skills: Fallacies and Guidelines.* Human Factors, Vol. 27:285-300.

510. Schneider, W.; Shiffrin, R.M. (1977). *Controlled and Automatic Human Information Processing. I. Detection Search and* Attention. Psychological Review, Vol. 84:1-66.

511. Schreuder, D.A. (1969). *Side Lights and Low Beam Headlights in Built-up Areas.* Institute for Road Safety Research, Leidschendam, The Netherlands.

512. Sedek, G.; Kofta, M. (1990). *When Cognitive Exertion does not yield Cognitive Gain: Towards an Informational Explanation of Learned Helplessness.* Journal of Personality and Social Psychology, Vol. 58:729-743.

513. Seiber, P.S.; Ellis, H.C. (1991). *Irrelevant Thoughts, Emotional Mood States and Cognitive Task Performance.* Memory and Cognition, Vol. 19:507-513.

514. Sekuler, R.; Ball, K. (1986). *Visual Localization: Age and Practice.* J Opt Soc Am A., Vol. 3:864-867.

515. Senders, J.W.; Kristofferson, A.B.; Levison, W.H.; Dietrch, C.W.; Ward, J.L. (1967). *The Attentional Demand of Automobile Driving.* Highway Research Record, Vol. 195:15-32.

516. Shannon, H.S. (1986). *Road Accident Data: Interpreting the British Experience with Particular Reference to Risk Homeostasis Theory.* Ergonomics, Vol. 29:1005-1015.

517. Sheridan, T.B. (1987). *Supervisory Control.* In: G. Salvendy, Ed., Handbook of Human Factors. Wiley New York.

518. Shiffrin, R.M. (1988). *Attention.* In: R.C. Atkinson, R.J. Herrnstein, G. Lindzey, R.D. Luce, Eds., Stevens' handbook of experimental psychology. 2nd ed. New York: John Wiley & sons.

519. Shiffrin, R.M.; Schneider, W. (1977). *Controlled and Automatic Human Information Processing: II. Perceptual Learning, Automatic Attending and a General Theory.* Psychol. Rev. 84:127-189.

520. Shimai, S.; Tanaka, M.; Terasaki, M. (1990). *Pleasantness and Unpleasantness of Environmental Sounds.* Perceptual and Motor Skills, Vol. 71:960-962.

521. Shinar, D. (1978). *Psychology on the Road: The Human Factor in Traffic Safety.* New York: John Wiley & Sons.

522. Shinar, D. (1985). *The Effects of Enforcement and Public Information on Compliance*. In: L. Evans, R.C. Schwing, Eds., Human Behavior and Traffic Safety. New York: Plenum Press; pp.385-412.

523. Shinar, D. (1993). *Traffic Safety and Individual Differences in Drivers' Attention and Information Processing Capacity*. Alcohol, Drugs and Driving 9:219-237.

524. Shinar, D. (1998). *Aggressive Driving: the Contribution of the Drivers and the Situation.* Transportation Research Part F1, pp. 137-160.

525. Shinar, D.; McDonald, S.T.; Treat, J.R. (1978). *The Interaction between Causally-implicated Driver Mental and Physical Conditions and Driver Errors causing Traffic Accidents: An Analytical Approach and a Pilot Study*. J. Safety Research, Vol. 10(16-23).

526. Shinar, D.; McDowell, E.D.; Rackoff, N.J.; Rockwell, T.H. (1978). *Field Dependence and Driver Visual Search Behaviour*. Human Factors, Vol. 20:553-559.

527. Shinar, D.; Stiebel, J. (1986). *The Effectiveness of Stationary Versus Moving Police Vehicles on Compliance with Speed Limit*. Human Factors 28:365-371.

528. Signori, E.I.; Bowman, R.G. (1974). *On the Study of Personality Factors in Research on Driving Behaviour*. Perception and Motor Skills, Vol. 38:1067-1076.

529. Simon, H.A. (1969). *The Science of the Artificial*. MIT Press, Cambridge,Mass.

530. Sivak, M. (1981). *Human Factors and Highway-accident Causation: Some Theoretical Considerations*. Accid. Anal. and Prev., Vol. 13:61-64.

531. Slovic, B.; Fischhoff, B.; Lichtenstein, S. (1979). Environment, Vol. 21:14.

532. Slovic, P. (1987). Science, pp.236-280.

533. Slovic, P.; Fischhoff, B.; Lichtenstein, S. (1982a). *Facts versus Fears: Understanding Perceived Risk*. In: D. Kahneman, P. Slovic, A. Tversky, Eds., Judgment under Uncertainty: Heuristics and Biases. Cambridge University Press, Cambridge.

534. Slovic, P.; Fischhoff, B.; Lichtenstein, S. (1982b). Risk Analysis, Vol. 2:83.

535. Slovic, P.; Fischhoff, B.; Lichtenstein, S. (1984). *Behavioural Decision Theory Perspectives on Risk and Safety*. Acta Psychologica, Vol. 56:183-203.

536. Slovic, P.; Fischhoff, B.; Lichtenstein, S.; Corrigan, B.; Coombs, B. (1977). *Preference for Insuring against Probable Small Losses: Insurance Implications*. Journal of Risk and Insurance, Vol. 44:237-258.

537. Smeed, R.J. (1949). *Some Statistical Aspects of Road Safety Research.* Journal of the Royal Statistical Society, Vol. 112:1-24.

538. Smeed, R.J. (1968). *Variations in the Pattern of Accident Rates in Different Countries and their Causes.* Traffic Engineering and Control, Vol. 9:364-371.

539. Smeed, R.J. (1972). *The Usefulness of Formulae in Traffic Engineering and Road Safety.* Accid. Anal. and Prev., Vol. 4:303-312.

540. Smiley, A.; Reid, L.; Fraser, M. (1980). *Changes in Driver Steering Control with Learning.* Human Factors, Vol. 22:401-415.

541. Snyder, H.L. (1976). *Braking Movement Time and Accelerator-Brake Separation.* Human Factors, Vol. 18, No. 2:201-204.

542. Soliday, S.M.; Allem, J.A. (1972).*Hazard Perception in Automobile Drivers: Age Differences.* HSRC Report, University of North Carolina.

543. Spearman, C. (1928). *The Origin of Error.* Journal of General Psychology, Vol. 1:29-53.

544. Stevens, S.S. (1957). *On the Psychophysical Law.* Psychol Rev., Vol. 64:153-181.

545. Stroop, J.R. (1935). *Studies of Interference in Serial Verbal Reactions.* Journal of Experimental Psychology, Vol. 18:643-662.

546. Summala, H. (1980). *How does it change Safety Margins if Overtaking is prohibited: A Pilot Study.* Accid. Anal. and Prev., Vol. 12:95-103.

547. Summala, H. (1985a). *Modeling Driver Behavior: A Pessimistic Prediction?* In: L. Evans, R.C. Schwing, Eds., Human behavior and traffic safety. New York: Plenum Press.

548. Summala, H. (1985b). *Valtatie 3:n Ruuhkatutkimus 1984.* Traffic Research Unit Report 1/1985, University of Helsinki.

549. Summala, H. (1986). *The Deterministic Man in a Stochastic World: Management on the Road.* In: B. Brehmer, H. Jungermann, P. Lourens, G. Sevon, Eds., New Directions in Research on Decision Making, pp.275-285. Elseviers Science Publishers, Amsterdam, North-Holland.

550. Summala, H. (1987a). *Why People drive too fast?* XII National Meeting on Road Safety, Kuusankoski, Finland.

551. Summala, H. (1987b). *Young Driver Accidents: Risk Taking of Failure of Skills?* Alcohol, Drugs and Driving, Vol. 3(3-4):79-91.

552. Summala, H. (1988) *Risk Control is not Risk Adjustment: The Zero-risk Theory of Driver Behavior and its Implications.* Ergonomics 31:491-506.

553. Summala, H. (1994). *Automization, Automation and Control of Attention among Car Drivers.* Paper presented at the 1st Automation Technology and Human Performance Conference, Washington DC.

554. Summala, H. (1996). *Accident Risk and Driver Behaviour.* Safety Science, Vol. 22:103-117.

555. Summala, H. (1997). *Hierarchical Model of Behavioural Adaptation and Traffic Accidents.* In: T. Rothengatter, E Carbonell, Eds., Traffic and Transport Psychology. Theory and Application. Elsevier, Amsterdam.

556. Summala, H.; Lamble, D.; Laakso, M. (1998). *Driving Experience and Perception of the Lead Car's Braking when Looking at In-car Targets*. Accid. Anal. and Prev., Vol. 30(4):401-407.

557. Summala, H.; Naatanen, R. (1974). *Perception of Highway Traffic Signs and Motivation*. J. Safety Res. 6:150-154.

558. Summala, H.; Nieminen, T.; Punto, M. (1996). *Maintaining Lane Position with Peripheral Vision during In-vehicle Tasks*. Human Factors, Vol. #8(3):442-451.

559. Summala, H.; Vierimaa, J. (1980). *Ajoneuvojen nopeudet, nopeuserot ja aikavälit: analyysejä autonkujettajien käyttäytymisestä (Driving speeds, speed differences and headways: analyses on driver behaviour)*. Road Administration, Helsinki.

560. Svenson, O. (1981). *Are We all less Risky and more Skilful than our Fellow Drivers?* Acta Psychologica, Vol. 47:143-148.

561. Syvänen, M. (1976). *Övervakningens betydelse för förarbeteendet*. Universitetet I Tammerfors, Psykologisk instisutt, Tammerfors.

562. Taylor, D.M. (1964). *Drivers' Galvanic Skin Response and the Risk of Accident*. Ergonomics, Vol. 7:439-451.

563. Teed, N.; Lund, A.K.; Knoblauch, R. (1993). *The Duration of Speed Reductions Attributable to Radar Detectors*. Accid. Anal. and Prev., Vol. 25:131-137.

564. Theeuwes, J. (1989). *Visual Selection: Exogenous and Endogenous Control: a Review of the Literature*. Report no. IZF 1989 C-3. Leiden, The Netherlands: TNO Institute for Perception.

565. Thierry, B.; Tattegrain-Veste, H.; Pauzié, A. (1996). *Ergonomics Evaluation of IVIS: Advantages in Developing a Driver's Model using A.I. Techniques.* ITS World Congress, Orlando. MIRA CD-ROM Publishing.

566. Tillman, W.A.; Hobbs, G.E. (1949). *The Accident Prone Automobile Driver: A Study of the Psychiatric and Social Background*. American Journal of Psychiatry, Vol.106:321-331.

567. Törnros, J. (1995). *Effect of Driving Speed on Reaction Time during Motorway Driving*. Accid. Anal. and Prev., Vol. 27(4):435-442.

568. Törnros, J. (1998). *Driving Behaviour in a Real and a Simulated Road Tunnel – A Validation Study.* Accid. Anal. and Prev., Vol. 30(4):497-503.

569. Treat, J.R.; Tumbas, N.S.; McDonald, S.T.; Shinar, D.; Hume, R.D.; Mayer, R.E.; Stansifer, R.L.; Castellan, N.J.; (1977). *Tri-level Study of the Causes of Traffic Accidents*. Report no. DOT-HS-034-3-535-77 (TAC). Bloomington, IN: Indiana University.

570. Treisman, A.M.; Gelade, G. (1980). *A Feature-integration Theory of Attention*. Cognitive Psychology 12:97-136.

571. Triggs, T.J.; Harris, W.G. (1982). *Reaction Time of Drivers to Road Stimuli*. Human Factors Report HFR-12. Monash University, Melbourne, Australia.

572. Tschernitscheck, E. (1978) *Verkehrssicherheitsprogramm eines Vertriebsunternehemens.* Berufsgenossenschaft.

573. Tversky, A.; Kahneman, D. (1974). *Judgement under Uncertainty: Heuristics and Biases.* Science, Vol. 185:1124-1134.

574. Tversky, A.; Kahneman, D. (1981). Science, Vol.211:453.

575. Twisk, D. (1995). *Liability of Novice Drivers and the Role of the Driver Training.* In: D. Lynam, (TRL); D. Twisk, (SWOV) Car Driver Training and Licensing System in Europe, TRL Report No. 147.

576. Tyler, T.R.; Rasinski, K.A.; Griffin, E. (1986). *Alternative Images of the Citizen.* American Psychology. 41:970-978.

577. Underwood, G, (1998). *Re-reading the Road – A Review of 'Eye Guidance in Reading and Scene Perception'.* Transportation Research, Part F, pp.53-54. Elsevier Science Ltd.

578. Underwood, G.; Everatt, J. (1992). *The Role of Eye Movements in Reading: Some Limitations of the Eye-mind Assumption*, pp.111-169. North-Holland, Amsterdam.

579. Utzelmann, H.D.; Jacobshagen, W. (1997). *Validation of the German System of Diagnosis and Rehabilitation of Traffic Offenders.* In: J.A. Rothengatter; E. Carbonell Vaya, Eds., Traffic and Transport Psychology: Theory and Application. Pergamon, Oxford.

580. Van der Colk, H. (1988). *Risky Behaviour resulting from Bounded Rationality.* Ergonomics, Vol. 31(4):485-490.

581. Van der Horst, A.R.A. (1990). *A Time-based Analysis of Road User Behaviour in Normal and Critical Encouters.* Thesis, Institute for Perception TNO, Soesterberg, The Netherlands.

582. Van der Molen, H.H.; Bötticher, A.M.T. (1987). *Risk Models for Traffic Participants: A Concerted Effort for Theoretical Operationalizations.* In: Rothengatter, J.A.; de Bruin, R.A., Eds., Road users and traffic safety. Asse, The Netherlands: Van Gorcum.

583. Van der Molen, H.H.; Bötticher, A.M.T. (1988). *A Hierarchical Risk Model for Traffic Participants.* Ergonomics, Vol. 31(4):537-555.

584. Van Elslande, P.; Alberton, L. (1997). *Scenarios-Types de Production de Terreur Humaine'dans l'accident de la Route.* Report 218. INRETS, Salon-de-Provence.

585. Van Winsum, W.; Brookhuis, K.A.; De Waard, D. (1999). *A Comparison of Different Ways to Approximate Time-to-line Crossing (TLC) during Car Driving.* Accid. Anal. and Prev., Vol. 32:47-56.

586. Van Winsum, W.; Brouwer, W. (1997). *Time-headway in Car-following and operational Performance during unexpected Braking.* Perceptual and Motor Skills, Vol. 84:1247-1257.

587. Van Winsum, W.; Godthelp, H. (1996). *Speed Choice and Steering Behavior in Curve Driving.* Human Factors, Vol. 38(3):434-441.

588. Van Winsum, W.; Heino, A. (1996). *Choice of Time-headway in Car-following and the Role of Time-to-collision Information in Braking*. Ergonomics, Vol. 39(4):579-592.

589. Verriest, G.; Barca, L.; Calbria, E., et al. (1983b). *The Occupational Visual Field, II: Practical Aspects. The Functional Visual Field in Abnormal Conditions and its Relationship to Visual Ergonomics, Visual Impairment and Job Fitness.* In: G. Verriest, Ed., Sixth International Visual Field Symposium, pp.281-326. Kluwer Academic Publishers, Junk, The Netherlands.

590. Verriest, G.; Barca, L.; Dubois-Poulsen, A., et al. (1983a). *The Occupational Visual Field, I: Theoretical Aspects. The normal Functional Visual Field.* In: G. Verriest, Ed., Fifth International Visual Field Symposium, pp.165-185. Kluwer Academic Publishers, Junk, The Netherlands.

591. Verwey, W.B.; Brookhuis, K.A.; Janssen, W.H. (1996). *Safety Effects of In-vehicle Information Systems*. Report TM-96-C002. Soesterberg, The Netherlands:TNO Human Factors Research Institute.

592. Verwey, W.B.; Veltman, H.A. (1996). *Detecting Short Periods of Elevated Workload: A Comparison of Nine Workload Assessment Techniques.* Journal of Experimental Psychology: Applied, Vol. 2:270-285.

593. Vinjé, M. (1981). *Children as Pedestrians: Abilities and Limitations*. Accident Analysis and Prevention, Vol. 13:225-240.

594. Vogel, R.; Rothengatter, J.A. (1984). *Motieven van Snelheidsgedrag op Autosnelwegen; Een Attitude Onderzoek*. Traffic Research Centre Report VK84-09, University of Groningen.

595. Von Neumann, J.; Morgenstern, O. (1964). *Theory of Games and Economic Behaviour*. Wiley Science Editions, New York.

596. Von Pupka, M. (1977). *Der Einfluss des Rauchens auf das Fahrverhalten un die Verkehrssicherheit*. Forschungsbericht FP7530 der Bundesanstalt für Strassenwesen, Bereich Unfallforschung.

597. Wagenaar, W.A. (1992). *Risk taking and Accident Causation.* In: J.F. Yates, Ed., Risk-taking Behavior. New York: John Wiley and Sons.

598. Wagenaar, W.A.; Reason, J.T. (1990). *Types and Tokens in Road Accident Causation*. Ergonomics, Vol. 33(10/11):1365-1375.

599. Walsh, K.W. (1978). *Neuropsychology: A Clinical Approach*. Churchill Livingstone, New York.

600. Ward, N.J.; Fairclough, S.H.; Humphreys, M. (1995). *The Effect of Task Automation in the Automotive Context: A Field Study of an Autonomous Intelligent Cruise Control System.*

International conferencej on experimental analysis and measurement of situation awareness. Daytona Beach, Florida, USA.

601. Warren, R.A.; Simpson, H.M. (1976). *The Young Driver Paradox*. Traffic Injury Research Foundation, Canada.
602. Wasielewski, P. (1984). *Speed as a Measure of Driver Risk: Observed Speeds versus Driver and Vehicle Characteristics*. Accid. Anal. and Prev., Vol. 16(2):89-103.
603. Watson, D. (1982). *The Actor and the Observer: How are their Perceptions of Causality Divergent*? Psychological Bulletin, Vol. 92:682-700.
604. Watts, G.R.; Quimby, A.R. (1980). *Aspects of Road Layout that affect Drivers' Perception and Risk Taking*. Report no. LR 920, Transport and Road Research Laboratory, Crowthorne, UK.
605. Weilbacher, W.M. (1984). *Advertising*. Lawrence Erlbaum, NJ.
606. Weinert, F.E.; Kluwe, R.H. (1987). *Metacognition, Motivation and Understanding*. Erlbaum, Hillsdale.
607. Welford, A.T. (1976). *Skilled Performance: Perceptual and Motor Skills*. Scott, Foresman and Company, Glenview, Ill.
608. Whyte, A. (1984). *Background Notes on Risk Perception, Man and the Biosphere Programme*. United Nations Educational, Scientific and Cultural Organization, Paris.
609. Wickens, C.D. (1984). *Processing Resources in Attention*. In: R. Parasuraman, D.R. Davies, Eds., Varieties of attention. Orlando, FL: Academic Press.
610. Wickens, C.D. (1992). *Engineering Psychology and Human Performance* (2nd ed). Harper Collins, New York.
611. Wiener, E.L.; Curry, R.E. (1980). *Flight Deck Automation: Promises and Problems*. Ergonomics, 23:995-1011.
612. Wikman, A.; Nieminen, T.; Summala, H. (1998). *Driving Experience and Time-sharing during In-car Tasks on Roads of Different Width*. Ergonomics, Vol. 41(3):358-372.
613. Wilde, G.J.S. (1976). *Social Interaction Patterns in Driver Behaviour: An Introductory Review*. Human Factors 18:477-492.
614. Wilde, G.J.S. (1981). *Objective and Subjective Risk in Drivers Response to Road Conditions: The Implications of the Theory of Risk Homeostasis for Accident Aetiology and Prevention*. Paper presented at the Seminar on the Implementation of Risk Taking Theories for Traffic Safety, West Berlin.
615. Wilde, G.J.S. (1982a). *The Theory of Risk Homeostasis: Implications for Safety and Health*. Risk Anal. 2:209-225.

616. Wilde, G.J.S. (1982b). *Critical Issues in Risk Homeostasis theory*. Risk Analysis, Vol. 2:249-258.

617. Wilde, G.J.S. (1985). *The Use of Incentives for the Promotion of Accident-free Driving*. Journal of Studies on Alcohol, Supplement 10:161-167.

618. Wilde, G.J.S. (1986a). *Notes on the Interpretation of Traffic Accident Data and of Risk Homeostasis Theory: A Reply to L. Evans*. Risk Analysis, Vol. 6:95-101.

619. Wilde, G.J.S. (1986b). *Beyond the Concept of Risk Homeostasis: Suggestions for Research and Application towards the Prevention of Accidents and Lifestyle-related Disease*. Accid. Anal. and Prev., Vol. 18:377-401.

620. Wilde, G.J.S. (1988) *Risk Homeostasis Theory and Traffic Accident: Propositions, Deductions and Discussion of Dissension in Recent Reactions*. Ergonomics 31:441-468.

621. Wilde, G.J.S. (1994). *Target Risk*. PDE Publications, Toronto, Ontario, Canada.

622. Wilde, G.J.S.; Ackersviller, M.J. (1981). *Accident Journalism and Traffic Safety Education*. Transport Safety, Report No. TP 3659 E, Cr 8202. Ottawa, Canada.

623. Wilde, G.J.S.; Claxton-Oldfield, S.P.; Patenius, P.H. (1985). *Risk Homeostasis in an Experimental Context*. In: L.Evans, R.C. Sching, Eds., Human Behaviour and Traffic Safety. pp.119-142. Plenum Press, New York.

624. Wilde, G.J.S.; Murdoch, P.A. (1982). *Incentive Systems for Accident-free and Violation-free Driving in the General Population*. Ergonomics, Vol. 25:879-890.

625. Williams, A.F.; Karpf, R.S. (1984). *Teenaged drivers and Fatal Crash Responsibility*. Law Police Quarterly, Vol. 6:101-113.

626. Williams, A.F.; O'Neill, B. (1974). *On-the-road Driving Records of Licensed Race Drivers*. Accid. Anal. and Prev., Vol. 6:263-270.

627. Wilson, R.J.; Jonah, B.A. (1988). *The Application of Problem Behavior Theory to he Understanding of Risky Driving*. Alcohol, Drugs and Driving, Vol. 4:173-191.

628. Wilson, T.; Greensmith, J. (1983). *Multivariate Analysis of the Relationship between Drivometer Variables and Drivers' Accident, Sex and Exposure Status*. Human Factors, Vol. 25(3):303-312.

629. Witkin, H.A.; Dyk, R.D.; Paterson, H.F.; Goodenough, D.R.; Karp, S.A. (1962). *Psychological Differentiation: Studies of Development*. Wiley, New York.

630. Wohl, J.G. (1961). *Man-Machine Steering Dynamics*. Human Factors, Vol. 3:222-228.

631. Wolffelaar, P.C. van; Rothengatter, J.A.; Brouwer, W.H. (1987). *Compensation Strategies of Elderly Drivers*. Contemporary Ergonomics 1987. London: Taylor and Francis.

632. Wong, Y.D.; Nicholson, A. (1992). *Driver Behavior at Horizontal Curves: Risk Compensation and the Margin of Safety*. Accid. Anal. and Prev., Vol. 24:425-436.

633. Wright, C. (1981). *Hysteresis and Collapse: A Theory of Parking Enforcement.* Proceedings of the Eighth Symposium on Transportation and Traffic Theory, Toronto.

634. Yang, Q.; Koutsopoulos, H.N. (….). *A Microscopic Traffic Simulator for Evaluation of Dynamic Traffic Management Systems*. Transportation Research, Part C, Vol. 4C(3):113-129.

635. Yu, J.; Williford, W.R. (1993). *Alcohol and Risk/Sensation Seeking: Specifying a Causal Model on High-risk Driving*. Journal of Addictive Diseases, Vol. 12:79-96.

636. Zaidel, D. (1992). *A Modeling Perspective on the Culture of Driving.* Accid. Anal. and Prev., Vol. 24(6):585-597.

637. Zaidel, D.; Paarlberg, W.T.; Shinar, D. (1979). *Indicators of Driver Inattention.* In: Proceeding of the Twenty-Third Conference of the American Association for Automotive Medicine, Louisville, Kentucky.

638. Zell, J.K. (1969). *Driver Eye-movement as a Function of Driving Experience*. Report No. IE-16, Columbus, Ohio.

639. Zimbardo, P.G. (1969). *The Human Choice: Individuation, Reason, and Order versus Deindividuation, Impulse, and Chaos.* In: W.J. Arnold, D. LeVine, Eds., Nebraska symposium on motivation, pp.237-307. University of Nebraska Press, Lincoln.

640. Zimbardo, P.G. (1975). *Transforming Experimental Research into Advocacy for Social Change*. In: M. Deutsch, H.A. Hornstein, Eds., Applying social psychology: Implications for research, practice and training. Hillsdale, NJ.

641. Zuckerman, M. (1979a). *Sensation Seeking: Beyond the Optimal Level of Arousal*. Erlbaum, Hillsdale, NJ.

642. Zuckerman, M. (1979b). *Sensation Seeking and Risk Taking.* In: C.E. Izard, Ed., Emotions in personality and psychopathology, pp.163-197. Plenum, New York.

643. Zuckerman, M. (1983c). *A Biological Theory of Sensation Seeking.* In: M. Zuckerman, Ed., Biological bases of sensation seeking, impulsivity, and anxiety, pp.37-76. Erlbaum, Hillsdale, NJ.

644. Zuckerman, M. (1990). *The Psychology of Sensation Seeking*. Journal of Personality, Vol. 58:313-345.

645. Zuckerman, M. (1994). *Behavioural Expressions and Biosocial Bases of Sensation Seeking.* University of Cambridge Press, Cambridge.

646. Zuckerman, M.; Buchsbaum, M.S.; Murphy, D.L. (1980). *Sensation Seeking and its Biological Correlates*. Psychological Bulletin, Vol. 88:187-214.

647. Zuckerman, M.; Eysenck, S.B.G.; Eysenck, H.J. (1978). *Sensation Seeking in England and America: Cross-cultural, Age, and Sex Comparisons*. Journal of Consulting and Clinical Psychology, Vol. 46:139-149.

648. Zuckerman, M.; Kolin, I.; Price, L.; Zoob, I. (1964). *Development of a Sensation Seeking Scale*. Journal of Consulting Psychology, Vol. 28:477-482.

649. Zwahlen, H.T. (1993). *Eye Scanning Rules for Drivers: How do they compare with Actual Observed Eye Scanning Behaviour*. Transportation Research Record, Vol. 1403:14-22.

Neuroscience

650. Abeles, M. (1982). *Role of the Cortical Neuron: Integrator or Coincidence Detector?* Israel Journal of Med. Sci., Vol. 18:83-92.

651. Abeles, M.; Bergman, H.; Margalit, E.; Vaadia, E. (1993). *Spatiotempral Firing Patterns in the Frontal Cortex of Behaving Monkeys*. J. Neurophysiol., Vol. 70:1629-1638.

652. Abeles, M.; Gerstein, G. (1988). *Detecting Spatiotemporal Firing Patterns among simultaneously recorded Single Neurons*. J. Neurophysiol., Vol. 60:909-924.

653. Adelman, P.K.; Zajonc, R.B. (1989). *Facual Efference and the Experience of Emotion.* Annual Review of Psychology, Vol. 40:249-280.

654. Adolphs, R. (1999). *Social Cognition and the Human Brain.* Trends in Cognitive Science, Vol. 3(12). Elsevier Science Ltd.

655. Adolphs, R.; et al. (1994). *Impaired Recognition of Emotion in Facial Expressions following Bilateral Damage to the Human Amygdala.* Nature, Vol. 372:669-672.

656. Adolphs, R.; et al. (1995). *Fear and the Human Amygdala.* J. Neurosci., Vol. 15:5879-5892.

657. Adolphs, R.; et al. (1996a). *Cortical Systems for the Recognition of Emotion in Facial Expressions*. J. Neurosci., Vol. 16:7678-7687.

658. Adolphs, R.; et al. (1996b). *The Right Second Somatosensory Cortex (S-II) is required to recognize Emotional Facial Expressions in Humans.* Soc. Neurosci. Abstr., Vol. 22:1854.

659. Adolphs, R.; et al. (1997). *Impaired Declarative Memory for Emotional Material following Bilateral Amygdala Damage in Humans.* Learn. Mem., Vol. 4:291-300.

660. Adolphs, R.; et al. (1999). *Recognition of Facial Emotion in Nine Subjects with Bilateral Amygdala Damage.* Neuropsychologia, Vol. 37:1111-1117.

661. Adi-Japha, E.; Freeman, N.H. (2000). *Regulation of Division of Labour between Cognitive Systems Controlling Action.* Cognition, Vol. 76:1-11.

662. Aggleton, J.P. (1993). *The Contribution of the Amygdala to Normal and Abnormal Emotional States.* Trends in Neurosciences, Vol. 16:328-333.

663. Albus, J. (1971). *A Theory of Cerebellar Function.* Mathematical Bioscience, Vol. 10:25-61.

664. Amaral, D.G. (1987). *Memory: Anatomical Organization of Candidate Brain Regions.* In: F. Plum, Ed., Handbook of Physiology. Section 1: The Nervous System, Vol. 5: Higher Functions of the Brain, pp. 211-294. American Physiological Society, Bethesda, MD.

665. Amaral, D.G.; et al. (1992). *Anatomical Organization of the Primate Amygdaloid Complex.* In: J.P. Aggleton, Ed., The Amygdala: Neurobiological Aspects of Emotion, Memory and Mental Dysfunction, Pp.1-66. John Wiley and Sons.

666. Amari, S.; Arbib, M.A. (1977). *Competition and Co-operation in Neural Sets.* In: J. Metzler, Ed., Systems Neuroscience. Academic Press, New York.

667. Amir, Y.; Harel, M.; Malach, R. (1993). *Cortical Hierarchy reflected in the Organization of Intrinsic Connections in Macaque Monkey Visual Cortex*. J. Comp. Neurol., Vol. 334:19-46.

668. Armony, J.L.; Servan-Schreiber, D.; Cohen, J.D.; LeDoux, J.E. (1995). *An Anatomically Constrained Neural Network Model of Fear Conditioning.* Behavioral Neuroscience, Vol. 109:246-257.

669. Arrington, K.F. (1994). *The Temporal Dynamics of Brightness Filling-In.* Vision Res., Vol. 34:3371-3387.

670. Baars, B.J. (1997). *In the Theatre of Consciousness: The Workspace of the Mind.* Oxford University Press.

671. Bachevalier, J.; Brickson, M.; Hagger, C. *Limbic-dependent Recognition Memory in Monkeys develops early in Infancy*. Neuroreport, Vol. 4:77-80.

672. Baddeley, A. (1982). *Your Memory: A User's Guide.* Macmillan, New York.

673. Baddeley, A.D. (1986). *Working Memory.* Claredon Press.

674. Baekelandt, V.; Arckens, L.; Annaert, W.; Eysel, U.T.; Orban, G.A.; Vandesande, F. (1994). *Alterations in GAP-43 and Synapsin Immunoreactivity provide Evidence for Synaptic Reorganization in Adult Cat Dorsal Lateral Geniculate Nucleus following Retinal Lesions.* Eur. J. Neurosci., Vol. 6:754-765.

675. Baillargeon, R. (1993). *The Object Concept revisited: New Directions in the Investigation of Infant's Physical Knowledge*. In: C. Granrud, Ed., Visual Perception and Cognition in Infancy, pp.265-315. LEA, London.

676. Baker, J.F.; Perlmutter, S.I.; Peterson, B.W.; Rude, S.A.; Robinson, F.R. (1987). *Simultaneous Opposing Adaptive Changes in Cat Vestibulo-Ocular Reflex Directions for Two Body Orientations.* Exp. Brain Res., Vol. 69:220-224.

677. Bandura, A. (1969). *Principles of Behaviour Modification* Holt, New York.

678. Banks, M.S.; Shannon, E. (1993). *Spatial and Chromatic Visual Efficiency in Human Neonates*. In: C.E. Granrud, Ed., Visual Perception and Cognition in Infancy, pp.1-46. Lawrence Erlbaum Associates, Hillsdale, NJ.

679. Bargh. J.A. (1992). *Being unaware of the Stimulus vs. unaware of its Interpretation: Why Subliminality per se does matter to Social Psychology*. In: R Bornstein, T Pittman, Eds., Perception without Awareness. Guilford, New York.

680. Baron-Cohen, S. (1995). *Mindblindness: An Essay on Autism and Theory of Mind.* MIT Press.

681. Bartlett, F.C. (1932). *Remembering*. Cambridge University Press, Cambridge.

682. Bateson, P.P.G.; Martin, P.R. (2000). *Design for a Life: How Behavior and Personality Develop.* Simon and Schuster.

683. Bear, M.F.; Malenka, R.C. (1994). *Synaptic Plasticity: LTP and LTD.* Current Opinion in Neurobiology, Vol. 4:389-399.

684. Bechara, A.; et al. (1994). *Insensitivity to Future Consequences following Damage to Human Prefrontal Cortex.* Cognition, Vol. 50:7-15.

685. Bechara, A.; et al. (1997). *Deciding Advantageously before Knowing the Advantageous Strategy.* Science, Vol. 275:1293-1295.

686. Ben-Porath-Yossef, S.; Waller, N.G. (1992). *Normal Personality Inventories in Clinical Assessment*. Psychol. Assess., Vol. 4:14-19.

687. Bertoncini, J.; Morais, J.; Bijeljar-Babic, R.; McAdams, S.; Peretz. I.; Mehler, J. (1989). *Dichotic Perception and Laterality in Neonates*. Brain Lang., Vol. 37:591-605.

688. Best, C.T. (1990). *The Emergence of Language-specific Phonemic Influences in Infant Speech Perception.* In: H.C. Nusbaum, J. Goodman, Eds., Development of Speech Perception: The Transition from Recognizing Speech Sounds to Spoken Words. MIT Press, Cambridge, MA.

689. Best, C.T. (1993). *Emergence of Language-specific Constraints in Perception of Non-native Speech: A Window on early Phonological Development*. In: B. De Boysson-Bardies, S. De Schonen, P. Jusczyk, P. McNeilage, J. Morton, Eds., Developmental Neurocognition: Speech and Face Processing in the First Year of Life, pp.289-304. Kluwer Academic Publishers, Dordrecht, Netherlands.

690. Best, C.T.; McRoberts, G.W.; Nomathemba, M.S. (1988). *Examination of Perceptual Reorganization for Non-native Speech Contrasts: Zulu Click Discrimination by English-speaking Adults and Infants*. J. Exp. Psychol. (Hum. Percept. Perform.), Vol. 13:345-360.

691. Binder, J.R.; Rao, S.M.; Hammeke, T.A.; Yetkin, F.Z.; Jesmonowicz, A.; Bandettini, P.A.; Wong, E.C.; Estkowski, L.D.; Goldstein, M.D.; Haughton, V.M.; Hyde, J.S. (1994). *Functional Magnetic Resonance Imaging of Human Auditory Cortex*. Ann. Neurol., Vol. 35:662-672.

692. Block, N. (1995). *On a Confusion about a Function of Consciousness*. Behavioral and Brain Sciences, Vol. 18:227-287.

693. Boardman, I.; Grossberg, S.; Myers, C.; Cohen, M.A. (1999). *Neural Dynamics of Perceptual Order and Context Effects for Variable-Rate Speech Syllables.* Percept. And Psychophys., Vol. 61:1477-1500.

694. Boecker, H.; Kleinschmidt, A.; Requardt, M.; Hänicke, W.; Merboldt, K.D.; Frahm, J. (1994). *Functional Cooperativity of Human Cortical Motor Areas during self-paced simple Finger Movements: A High-resolution MRI Study*. Brain, Vol.117:1231-1239.

695. Boller, K.; Rovee-Collier, C. (1992). *Conrtextual Coding and Recoding of Infant Memory*. J. Exp. Child Psychol., Vol. 52:1-23.

696. Bonnet, M.; Requin, J. (1982). *Long Loop and Spinal Reflexes in Man during Preparation for intended Directional Hand Movements*. J. Neurosci., Vol. 2:90-96.

697. Born, R.R.; Tootell, R.B.H. (1992). *Segregation of Global and Local Motion Processing in Primate Middle Temporal Visual Area.* Nature, Vol. 357:497-499.

698. Bornstein, R.F. (1992). *Subliminal Mere Exposure Effects.* In: R.F. Bornstein, T.S. Pittman, Eds., Perception without Awareness: Cognitive, Clinical, and Social Perspectives, pp. 191-210. Guilford, New York.

699. Bower, G. (1992). *How might Emotions affect Learning?* In: S.-A. Christianson, Ed., Handbook of Emotion and Memory: Research and Theory. Erlbaum, Hillsdale, NJ.

700. Bowers, K.S. (1984). *On being unconsciously influenced and informed.* In: K.S. Bowers, D. Meichenbaum, Eds., The Unconscious reconsidered, pp. 227-272. Wiley, New York.

701. Bowers, K.S.; Meichenbaum, D. (1984). *The Unconscious reconsidered.* Wiley, New York.

702. Bradley, M.M.; et al. (1992). *Remembering Pictures: Pleasure and Arousal in Memory.* J. Exp. Psychol. Learn. Mem. Cognit., Vol. 18:379-390.

703. Bradski, G.; Carpenter, G.A.; Grossberg, S. (1994). *STORE Working Memory Networks for Storage and Recall of Arbitrary Sequences.* Biol. Cyber., Vol. 71:469-480.

704. Brashers-Krug, T.; Shadmehr, R.; Bizzi, E. (1996). *Consolidation in Human Motor memory.* Nature, Vol. 382:252-255.

705. Brecht, M.; et al. (1997). *Collicular Sarcade Vectors defined by Synchronization*. Soc. Neurosci., Vol. 23:843.

706. Brecht, M.; et al. (1999). *Patterns of Synchronization in the Superior Colliculus of Anesthetized Cats*. Journal of Neuroscience, Vol. 19:3567-3579.

707. Bremner, J.D.; Randall, T.; Scott, T.M.; Brunen, R.A.; Seibyl, J.P.; Southwick, S.M.; Delaney, R.C.; McCarthy, G.; Charney, D.S.; Innis, R.B. (1995). *MRI-based Measurement of Hippocampal Volume in Patients with combat-related PTSD.* American Journal of Psychiatry, Vol. 152:973-981.

708. Brodmann, K. (1909). *Vergleichende Lokalisationslehre der Grosshirnrinde in ihren Prinzipien dargestellt auf Grund des Zellenbaues*. Barth, Lepzig. (Title translation: Doctorine of the comparative localization of the cerebral cortex: a description based on the cellular organization.) In: Brodmann's 'Localisation in the Cerebral Cortex', L. Garey, Ed. Smith-Gordon, London.

709. Brosch, M.; et al. (1997). *Stimulus-dependent Modulations of Correlated High-Frequency Oscillations in Cat Visual Cortex.* Cereb. Cortex, Vol. 7:70-76.

710. Brown, R.J.; Norcia, A.M. (1997). *A Method for investigating Binocular Rivalry in Real-time with the Steady-state VEP*. Vis. Res., Vol. 37:2401-2408.

711. Bullier, J.; Hupé, J.M.; James, A.; Girard, P. (1996). *Functional Interactions between Areas V1 and V2 in the Monkey.* J. Physiology (Paris), Vol. 90:217-220.

712. Bullock, D.; Bongers, R.M.; Lankhorst, M.; Beek, P.J. (1999). *A Vector-Integration-to-Endpoint Model for Performance of Viapoint Movements.* Neural Networks, Vol. 12:1-29. Elsevier Science Ltd.

713. Bullock, D.; Cisek, P.; Grossberg, S. (1998). *Cortical Networks for Control of Voluntary Arm Movements under Variable Force Conditions.* Cerebral Cortex, Vol. 8:48-62.

714. Bullock, D.; Fiala, J.C.; Grossberg, S. (1994). *A Neural Model of Timed Response Learning in the Cerebellum.* Neural Networks, Vol. 7:1101-1114.

715. Bullock, D.; Grossberg, S.; Mannes, C. (1993). *A Neural Network Model for Cursive Script Production.* Biol. Cybern., Vol. 70:15-28.

716. Burnham, D. (1993). *Visual Recognition of Mother by Young Infants: Facilitation by Speech.* Perception, Vol. 22:1133-1153.

717. Cahill, L.; et al. (1996). *Amygdala Activity at Encoding Correlated with Long-Term, Free Recall of Emotional Information.* Proc. Natl. Acad. Sci. U.S.A., Vol. 93:8016-8021.

718. Campbell, B.A.; Jaynes, J. (1966). *Reinstatement.* Psychological Review, Vol. 73:478-480.

719. Campeau, S.; Liang, K.C.; Davis, M. (1990). *Long-term Retention of Fear-potentiated Startle following a Short Training Session.* Animal Learning and Behavior, Vol. 18(4):462-468.

720. Carder, R.K.; Hendry, S.H. *Neuronal Characterization, Compartemental Distribution and Activity-dependent Regulation of Glutamate Immunoreactivity in Adult Monkey Striate Cortex*. J. Neurosci., Vol. 14:242-262.

721. Carpenter, G.A.; Grossberg, S. (1987a). *A Massively Parallel Architecture for a Self-Organizing Neural Pattern Recognition Machine.* Comp. Vis. Graph. Image Proc., Vol. 37:54-115.

722. Carpenter. G.A.; Grossberg, S. (1987b). *ART 2: Stable Self-organization of Pattern Recognition Codes for Analog Input Patterns.* Appl. Opt., Vol. 26:4919-4930.

723. Carpenter, G.A.; Grossberg, S. (1987c). *Neural Dynamics of Category Learning and Recognition: Attention, Memory Consolidation and Amnesia.* In: S. Grossberg, Ed., The Adaptive Brain, I: Cognition, Learning, Reinforcement and Rhythm, Pp.238-286. Elsevier/North-Holland, Amsterdam.

724. Carpenter, G.A.; Grossberg, S. (1988). *Neural Dynamics of Category Learning and Recognition: Attention, Memory Consolidation and Amnesia.* In: J. Davis, R. Newburgh and E Wegman, Eds., Brain Structure Learning and Memory. AAAS Symposium Series.

725. Carpenter, G.A.; Grossberg, S. (1990). *ART 3: Hierarchical Search using Chemical Transmitters in Self-Organizing Pattern Recognition Architectures.* Neural Networks, Vol. 3:129-152.

726. Carpenter, G.A.; Grossberg, S. (1991). *Pattern Recognition by Self-Organizing Neural Networks.*MIT Press, Cambridge, MA.

727. Carpenter, G.A.; Grossberg, S. (1996). *Adaptive Resonance Theory.* In: J.D. Irwin, Ed., The Industrial Electronics Handbook, Pp.1286-1298. CRC Press.

728. Caspi, A.; Begg, D.; Dickson, N.; Harrington, H.L.; Langley, J.; Moffitt, T.E.; Silva, P.A. (1997). *Personality Differences predict Health-Risk Behaviors in Young Adulthood: Evidence from a Longitudinal Study.* Journal of Personality and Social Psychology, Vol. 73:1052-1-63.

729. Castelo-Branco, M.; et al. (2000). *Neural Synchrony Correlates with Surface Segregation Rules*. Nature, Vol. 405:685-689.

730. Chapman, P.R.; Groeger, J.A. (1998). *Arousal and Memory for Everyday Events: Subjective Risk and the Recognition of Driving Situations.* Manuscript submitted for publication.

731. Chaudhuri, A.; Matsubara, J.A.; Cynader, M.S. (1995). *Neuronal Activity in Primate Visual Cortex assessed by Immunostaining for the Transcription Factor Zif268*. Vis. Neurosci., Vol. 12:35-50.

732. Christianson, S.-A. (1992). *Eyewitness Memory for Stressful Events: Methodological Quandaries and Ethical Dilemmas.* In: S.-A. Christianson, Ed., Handbook of Emotion and Memory: Research and Theory. Erlbaum, Hillsdale, NJ.

733. Chugani, H.T.; Phelps, M.E.; Mazziotta, J.C. (1987). *Positron Emission Tomography Study of Human Brain Functional Development*. Ann. Neurol., Vol. 22:487-497.

734. Churchland, P. (1984). *Matter and Consciousness*. MIT Press, Cambridge.

735. Churchland, P.S.; Sejnowski, T.J. (1990). In: L.Nadel, L. Cooper, P. Culicover, M. Harnish, Eds., Neural Connections, Mental Computation. MIT Press, Cambridge.

736. Cisek, P.; Bullock, D.; Grossberg, S. (1998). *A Cortico-Spinal Model of Reaching and Proprioception under Multiple Task Constraints.* J. Cognit. Neurosci., Vol. 10:425-444.

737. Cloninger, C.R. (1994). *Temperament and Personality*. Current Opinion in Neurobiology, Vol. 4:266-273.

738. Cloninger, C.R.; Svrakic, D.M.; Przybeck, T.R. (1993).*A Psychobiological Model of Temperament and Character*. Arch. Gen. Psychiatry, Vol. 50:975-990.

739. Cohen, J.; Dunbar, K.; McClelland, J. (1990). *On the Control of Automatic Processes: A Parallel Distributed Processing Model of the Stroop Effect.* Psychological Review, Vol. 97:332-361.

740. Collier, G.L.; Wright, C.E. (1995). *Temporal Rescaling of Simple and Complex Ratios in Rhythmic Tapping*. J. Exp. Psychol. (Hum. Percept. Perform.), Vol. 21:602-627.

741. Coltheart, M. (1999). *Modularity and Cognition.* Trends Cognit. Sci., Vol. 3:115-119.

742. Conel, J.L. (1939-1967). *The Postnatal Development of the Human Cerebral Cortex*. Vol. 1-8. Harvard University Press, Cambridge, MA.

743. Cowan, R.L.; Wilson, C.J. (1994). *Spontaneous Firing Patterns and Axonal Projection of Single Corticostriatal Neurons in the Rat Medial Agranular Cortex*. J. Neurophysiol., Vol. 71:17-32.

744. Crick, F. (1989). *The Recent Excitement about Neural Networks*. Nature, Vol. 337:129-132.

745. Crick, F.; Asanuma, C. (1986). *Certain Aspects of the Anatomy and Physiology of the Cerebral Cortex.* In: J. McClelland and D. Rumelhart, Eds., Parallel Distributed Processing, pp.333-371. MIT Press, Cambridge, MA.

746. Crick, F.; Koch, C. (1990). *Some Reflections on Visual Awareness*. Cold Spring Harbor Symposium on Quantitative Biology, Vol. 15:953-962.

747. Crick, F.; Koch, C. (1990). *Towards a Neurobiological Theory of Consciousness*. Semin. Neurosci., Vol. 2:263-275.

748. D'Esposito, M.; Detre, J.; Alsop, D.; Shin, R.; Atlas, S.; Grossman, M. (1995). *The Neural Basis of the Central Executive System of Working Memory.* Nature, Vol. 378:279-281.

749. Damasio, A.R. (1990). *Synchronous Activation in Multiple Cortical Regions: A Mechanism for Recall.* Semin. Neurosci., Vol. 2:287-296.

750. Damasio, A.R. (1994). *Descartes' Error: Emotion, Reason, and the Human Brain.* Grosset/Putnam.

751. Damasio, A.R. (1996). *The Somatic Marker Hypothesis and the Possible Functions of the Prefrontal Cortex.* Phil. Trans. R. Soc. London Ser. B, Vol. 351:1413-1420.

752. Damasio, A.R. (1999). *The Feeling of What Happens.* Harcourt Brace.

753. Damasio, A.R.; Tranel, D.; Damasio, H. (1990). *Individuals with Sociopathic Behavior caused by Frontal Damage fail to respond Automatically to Social Stimuli.* Behav. Brain Res., Vol. 41:81-94.

754. Darian, S.C.; Gilbert, C.D. (1994). *Axonal Sprouting accompanies Functional Reorganization in Adult Cat Striate Cortex*. Nature, Vol. 368:737-740.

755. Davis, M. (1994). *The role of the Amygdala in Emotional Learning.* Internat. Rev. of Neurobiol., Vol. 36:225-265.

756. Dawkins, R. (1982). *The Extended Phenotype: The Gene as the Unit of Selection*. Freeman, San Francisco.

757. De Boysson-Bardies, B. (1993). *Ontogeny of Language-specific Syllabic Production.* In: B. De Boysson-Bardies, S. De Schonen, P. Jusczyk, P. McNeilage, J. Morton, Eds., Developmental Neurocognition: Speech and Face Processing in the First Year of Life, pp.353-363. Kluwer Academic Publishers, Dordrecht, Netherlands.

758. Decety, J.; Perani, D.; Jeannerod, M.; Bettinardi, V.; Tadary, B.; Woods, R.; Mazziotta, J.C.; Fazio, F. (1994). *Mapping Motor Representations with Positron Emission Tomography.* Nature, Vol. 371:600-602.

759. Decety, J.; Sjoholm, H.; Ryding, E.; Sternberg, G.; Ingvar, D.H. (1990). *The Cerebellum participates in Mental Activity.* Brain Res. Vol. 553:313-317.

760. Dehaene-Lambertz, G.; Dehaene, S. (1994). *Speed and Cerebral Correlates of Syllable Discrimination in Infants.* Nature, Vol. 370:292-295.

761. Delacour, J. (1997). *Neurobiology of Consciousness: An Overview.* Behav. Brain Res., Vol. 85:127-141.

762. Dennett, D. (2001). *Are we explaining Consciousness yet?* Cognition, Vol. 79:221-237. Elsevier Science.

763. Desimone, R. (1992). *Neural Circuits for Visual Attention in the Primate Brain.* In: G.A. Carpenter and S Grossberg, Eds., Neural Networks for Vision and Image Processing, Pp. 343-364. MIT Press, Cambridge, MA.

764. DeYoe, E.A.; Van Essen, D.C. (1988). *Concurrent Processing Streams in Monkey Visual Cortex.* Trends in Neurosci., Vol. 11:219-226.

765. Diesmann, M.; et al. (1999). *Stable Propagation of Synchronous Spiking in Cortical Neural Networks.* Nature, Vol. 402:529-533.

766. Diorio, D.; Viau, V.; Meaney, M.J. (1993). *The Role of the Medial Prefrontal Cortex (Cingulate Gyrus) in the Regulation of Hypothalamic-pituitary-adrenal Responses to Stress.* Journal of Neuroscience, Vol. 13:3839-3847.

767. Dolphin, L.T. (1988). *Jesus: Lord of Time and Space.* New Leaf Press, AR.

768. Donoghue, J.P. (1995). *Plasticity of Adult Sensorimotor Representations.* Current Opinion in Neurobiology, Vol. 5:749-754.

769. Donoghue, J.P.; Sanes, J.N. (1996). *Plasticity of Cortical Representations and its Implication for Neurorehabilitation.* In:B.T. Shahani, Ed., Principles and Practice of Rehabilitation Medicine. Williams and Wilkins, Baltimore.

770. Douglas, R.J.; Koch, C.; Mahowald, M.; Martin, K.A.C.; Suarez, H.H. (1995). *Recurrent Excitation in Neocortical Circuits.* Science, Vol. 269:981-985.

771. Duffy, C.J.; Wurtz, R.H. (1995). *Medial Superior Temporal Area Neurons respondto Speed Patterns in Optic Flow.* J. Neurosci., Vol. 17:2839-2851.

772. Duncan, J.; Williams, P.; Nimmo-Smith, I.; Brown, I.D. (1993). *The Control of Skilled Behavior: Learning, Intelligence, and Distraction.* In: D.E. Meyer; S. Kornblum, Eds., Attention and Performance XIV: Synergies in Experimental Psychology, Artificial Intelligence, and Cognitive Neuroscience, Pp.323-341. MIT Press, Cambridge, MA.

773. Dyer, M.G. (1987). *Emotions and their Computations: Three Computer Models.* Cognition and Emotion, Vol. 1:323-347.

774. Eckhorn, R.; Bauer, R.; Jordan, W.; Brosch, M.; Kruse, W.; Munk, M.; Reitbock, H.J. (1988). *Coherent Oscillations: A Mechanism of Feature Linking in the Visual Cortex?* Biol. Cyber., Vol. 60:121-130.

775. Edelman, G.M. (1987). *Neural Darwinism: The Theory of Neuronal Group Selection.* Basic Books.

776. Egusa, H. (1983). *Effects of Brightness, Hue, and Saturation on Perceived Depth between Adjacent Regions in the Visual Field.* Perception, Vol. 12:167-175.

777. Ehrlich, P.R. (2000). *Human Natures: Genes, Cultures, and the Human Prospect.* Island Press, California.

778. Eichenbaum, H.; Otto, T. (1992). *The Hippocampus: What does it do?* Behavioral and Neural Biology, Vol. 57: 2-36.

779. Eimas, P.D.; Miller, J.L.; Jusczyk, P.W. (1987). *On Infant Speech Perception and the Acquisition of Language.* In: S. Harnad, Ed., Categorical Perception: The Groundwork of Cognition, pp.161-195. Cambridge University Press, New York.

780. Ekman, P. (1993). *Facial Expression and Emotion.* American Psychologist, Vol. 48.

781. Elman, J. (1990). *Finding Structure in Time.* Cognitive Science, Vol. 14:179-212.

782. Elman, J. (1993). *Learning and Development in Neural Networks: The Importance of Starting Small.* Cognition, Vol. 48:71-99.

783. Elman, J.L.; Bates, E.A.; Johnson, M.H. (1996). *Rethinking Innateness: A Connectionist Perspective on Development.* MIT Press.

784. Emery, N.J.; et al. (1998). *Role of the Amygdala in Dyadic Social Interactions and the Stress Response in Monkeys.* Soc. Neurosci. Abstr., Vol. 24:780.

785. Engel, A.K.; et al. (1991). *Interhemispheric Synchronization of Oscillatory Neuronal Responses in Cat Visual Cortex.* Science, Vol. 252:1177-1179.

786. Engel, A.K.; et al. (1997). *Temporal Coding in the Visual Cortex: New Vistas on Integration in the Nervous System.* Trends Neurosci., Vol. 15:218-226.

787. Engel, A.K.; et al. (1999). *Temporal Binding, Binocular Rivalry and Consciousness.* Conscious. Cognit., Vol. 8:128-151.

788. Erdelyi, M. (1985). *Psychoanalysis: Freud's Cognitive Psychology.* Freeman, New York.

789. Ericcson, K.A.; Simon, H. (1984). *Protocol Analysis: Verbal Reports as Data.* MIT Press, Cambridge.

790. Estes, W.K. (1993). *Concepts, Categories and Psychological Science*. Psych. Science, Vol. 4:143-153.

791. Farah, M.; McClelland, J. (1991). *A Computational Model of Semantic Memory Impairment: Modality Specificity and Emergent Category Specificity*. Journal of Experimental Psychology: General, Vol. 120:339-357.

792. Farah, M.J.; Weisberg, L.L.; Monheit, M.; Peronnet, F. (1990). *Brain Activity underlying Visual Imagery. Event-related Potentials during Mental Image Generation*. J. Cogn. Neurosci., Vol. 1:302-316.

793. Farmer, M.E.; Bryson, S.E.; Klein, R. (1995). *Dyslexia: The growing Evidence for a Temporal Processing Deficit*. Psychonomic Bull. Review.

794. Faubert, J.; Von Grunau, M. (1995). *The Influence of Two Spatially Distinct Primers and Attribute Priming on Motion Induction.* Vision Res., Vol. 35:3119-3130.

795. Felleman, D.J.; Van Essen, D.C. (1991). *Distributed Hierarchical Processing in the Primate Cerebral Cortex*. Cereb. Cortex, pp.1-47.

796. Fenson, L.; Dale, P.S.; Reznick, J.S.; Bates, E.; Thal, D. (1994). *Variability in Early Communicative Development*. Monographs of the Society for Research in Child Development.

797. Ferguson, C.A.; Menn, L.; Stoel-Gammon, C.; (1992). *Phonological Development: Models, Research, Implications*. York Press, Timonium, Maryland.

798. Fiala, J.C.; Grossberg, S.; Bullock, D. (1996). *Metabotropic Glutamate Receptor Activation in Cerebellar Purkinje Cells as Substrate for Adaptive Timing of the Classically Conditioned Eye-Blink Response.* Journal of Neuroscience, Vol. 5:2745-2754.

799. Fiala, J.C.; Grossberg, S.; Bullock, D. (1996). *Metabotropic Glutamate Receptor Activation in Cerebellar Purkinje Cells as Substrate for Adaptive Timing of the Classically Conditioned Eye-Blink Response.* J. Neurosci., Vol. 16:3760-3774.

800. Fiez, J.A.; Tallal, P.; Raichle, M.E.; Miezin, F.M.; Katz, W.F.; Petersen, S.E. (1994). *PET Studies of Auditory and Phonological Processing: Effects of Stimulus Characteristics and Task Demands*. J. Cogn. Neuroscience.

801. Filimonoff, (1932). In: *über die Variabilität der Grosshirnindenstruktur. Mittelung. II: Regio occipitalis beim erwachsenen Menschen*. J. Psychol. Neurol., Vol. 44:1-96. (Title translation: On the variability of the structure of the cerebral cortex. Report II. The occipital region in the human adult.)

802. FitzGerald, M.J.T. (1995). *Neuroanatomy: Basic and Clinical.* Bailliere Tindall, Great Britain.

803. Flach, J.M. (1999). *Beyond Error: The Language of Coordination and Stability.* In: P.A. Hancock, Ed., Human Performance and Ergonomics, Pp.109-128. Academic Press, San Diego.

804. Flaherty, A.W.; Graybiel, A.M. (1994). *Input-output Organization of the Sensorimotor Striatum in the Squirrel Monkey*. J. Neurosci., Vol. 14:599-610.

805. Flege, J.E. (1993). *Production and Perception of a Novel, Second-language Phonetic Contrast*. J. Acoust. Soc. Am., Vol. 93:1589-1608.

806. Flew, A. (1964). *Body, Mind and Death.* Macmillan, New York.

807. Fodor, J.A. (1983). *The Modularity of Mind.* MIT Press.

808. Fodor, J.A.; Pylyshyn, Z.W. (1988). *Connectionism and Cognitive Architecture: A Critical Analysis*. Cognition, Vol. 28:3-71.

809. Foley, J.M. (1980). *Binocular Distance Perception.* Psychol. Rev., Vol. 87:411-434.

810. Fox, P.T.; Woldorff, M.G. (1994). *Integrating Human Brain Maps*. Current Opinion in Neurobiology, Vol. 4:151-156.

811. Frank, R.H. (1988). *Passions within Reason: The Strategic Role of the Emotions.* Norton, New York.

812. Freiwald, W.A.; et al. (1995). *Stimulus Dependent Inter-columnar Synchronization of Single Unit Responses in Cat Area17*. Neuro. Report, Vol. 6:2348-2352.

813. Fried, I.; Gozal, D.; Kirlew, K.A.T.; Hathout, G.M.; Tang, H.; Zhang, J.; Harper, R.M. (1994). *Dynamic Magnetic Resonance Imaging of Human Rolandic Cortex*. Neuroreport, Vol. 5:1593-1596.

814. Fries, P.; et al. (1997). *Synchronization of Oscillatory Responses in Visual Cortex Correlates with Perception in Interocular Rivalry*. Proc. Natl. Acad. Sci. (U.S.A.), Vol. 94:12699-12704.

815. Fries, P.; et al. (2001). *Modulation of Oscillatory Neuronal Synchronization by Selective Visual Attention*. Science, Vol. 291:1560-1563.

816. Frijda, N.H. (1993). *The Place of Appraisal in Emotion.* Cognition and Emotion, Vol. 7:357-388.

817. Frijda, N.; Swagerman, J. (1987). *Can Computers Feel? Theory and Design of an Emotional System.* Cognition and Emotion, Vol. 1:235-257.

818. Fujita, I.; Tanaka, K.; Ito, M.; Cheng, K. (1992). *Columns for Visual Features of Objects in Monkey Inferotemporal Cortex*. Nature, Vol. 360:343-346.

819. Fuster, J.M. (1989). *The Prefrontal Cortex*. Raven, New York.

820. Gallese, V.; Goldman, A. (1999). *Mirror Neurons and the Simulation Theory of Mind-Reading.* Trends Cognit. Sci., Vol. 2:493-500.

821. Gandolfo, F.; Mussa-Ivaldi, F.A.; Bizzi, E. (1996). *Motor Learning by Field Approximation.* Proc. Natl. Acad. Sci., Vol. 93:3843-3846.

822. Gardner, H. (1987). *The Mind's new Science: A History of the Cognitive Revolution.* Basic Books, New York.

823. Garraghty, P.E.; Kaas, J.H. (1991). *Functional Reorganization in Adult Monkey Thalamus after Peripheral Nerve Injury.* Neuroreport, Vol. 2:747-750.

824. Gauthier, I.; et al. (1999). *Activation of the Middle Fusiform 'Face Area' increases with Expertise in Recognizing Novel Objects.* Nat. Neurosci., Vol. 2:568-573.

825. Gawne, T.; Richmond, B. (1993). *How independent are the Messages carried by adjacent Inferior Temporal Cortical Neurons?* J. Neurosci., Vol. 13:2758-2771.

826. Gazzaniga, M.S. (1988). *Brain Modularity: Towards a Philisophy of Conscious Experience.* In: A.J. Marcel, E. Bisiach, Eds., Consciousness in contemporary Science. Clarendon Press, Oxford.

827. Gazzaniga, M.S.; LeDoux, J.E. (1978). *The Integrated Mind.* Plenum, New York.

828. Georgopolous, A.P.; Schwartz, A.B.; Kettner, R.E. (1986). *Neuronal Population Coding of Movement Direction.* Science, Vol. 233:1416-1419.

829. Geyer, S.; Ledberg, A.; Schleicher, A.; Kinomura, S.; Schormann, T.; Bürgel, U.; Klingberg, T.; Larsson, J.; Zilles, K.; Roland, P.E. (1996). *Two different Areas within the Primary Motor Cortex of Man.* Nature, Vol. 382:3462-3474.

830. Ghahramani, Z.; Wolpert, D.M. (1997). *Modular Decomposition in Visuomotor Learning.* Nature, Vol. 386:392-395.

831. Ghose, G.; Maunsell, J. (1999). *Specialized Representations in Visual Cortex: A Role for Binding?* Neuron, Vol. 24:79-85.

832. Gold, P.E. (1992). *Modulation of Memory Processing: Enhancement of Memory in Rodents and Humans.* In: L.R. Squire, N. Butters, Eds., Neuropsychology of Memory, pp. 402-414. Guilford, New York.

833. Goldfield, B.; Reznick, J.S. (1992). *Rapid Change in Lexical Development in Comprehension and Production.* Developmental Psychology, Vol. 28:406-413.

834. Goldman, P.; Nauta, W. (1977). *Columnar Distribution of Cortico-Cortical Fibers in the Frontal Association, Limbic and Motor Cortex of the developing Rhesus Monkey.* Brain Res., Vol. 122:393-413.

835. Goldman-Rakic, P.S. (1987). *Circuitry of Primate Prefrontal Cortex and Regulation of Behaviour by Representational Memory.* In: F. Plum, Ed., Handbook of Physiology. Section

1: The Nervous System, Vol. 5: Higher Functions of the Brain, pp.373-417. American Physiological Society, Bethesda, MD.

836. Goleman, D. (1995). *Emotional Intelligence.* Bantam, New York.

837. Goodale, M.A.; Milner, D. (1992). *Separate Visual Pathways for Perception and Action.* Trends in Neurosci., Vol. 15:10-25.

838. Gopnik, A.; Meltzoff, A. (1987). *The Development of Categorisation in the Second Year and its Relation to the other Cognitive and Linguistic Developments*. Child Development, Vol. 58:1523-1531.

839. Gove, A.; Grossberg, S.; Mingolla, E. (1995). *Brightness, Perception, Illusory Contours, and Corticogeniculate Feedback.* Visual Neurosci., Vol. 12:1027-1052.

840. Goy, R.W.; McEwen, B.S. (1980). *Sexual Differentiation of the Brain*. MIT Press, Cambridge, Massachusetts.

841. Grafton, S.T.; Woods, R.P.; Mazziotta, J.C. (1993). *Within-arm Somatotopy in Human Motor Areas determined by Positron Emission Tomography Imaging of Cerebral Blood Flow*. Exp. Brain Res., Vol. 95:172-176.

842. Grant, S.G.N.; Silva, A.J. (1994). *Targeting Learning*. Trends Neurosci., Vol. 17:71-75.

843. Gray, C.M.; et al. (1989). *Oscillatory Responses in Cat Visual Cortex exhibit Inter-columnar Synchronization which reflects Global Stimulus Properties*. Nature, Vol. 338:334-337.

844. Gray, C.M.; Singer, W. (1989). *Stimulus-Specific Neuronal Oscillations in Orientation Columns of Cat Visual Cortex.* Proc. Natl. Sci. USA, Vol. 86:1698-1702.

845. Graybiel, A.M. (1995). *Building Action Repertoires: Memory and Learning Functions of the Basal Ganglia*. Current Opinion in Neurobiology, Vol. 5:733-741.

846. Graybiel, A.M.; Aosaki, T.; Flaherty, A.W.; Kimura, M. (1994). *The Basal Ganglia and Adaptive Motor Control*. Science, Vol. 265:1926-1831.

847. Graybiel, A.M.; Kimura, M. (1995). *Adaptive Neural Networks in the Basal Ganglia*. In: J.C. Houk, J.L. Davis, D.G. Beiser, Eds., Models of Information Processing in the Basal Ganglia, pp.103-116. MIT Press, Cambridge, Massachusetts.

848. Graziano, M.S.A.; Andersen, R.A.; Snowden, R.J. (1994). *Tuning of MST neurons to Spiral Motions*. J. Neurosci., Vol.14:54-67.

849. Graziano, M.S.A.; Gross, C.G. (1993). *A Bimodal Map of Space: Somatosensory Receptive Fields in the Macaque Putamen with corresponding Visual Receptive Fields*. Exp. Brain Res., Vol. 97:96-109.

850. Graziano, M.S.A.; Gross, C.G. (1994). *The Representation of Extrapersonal Space: A possible Role for Bimodal, Visual-tactile Neurons*. In: M.S. Gazzaniga, Ed., The Cognitive Neuroscience. MIT Press, Massachusetts.

851. Green, K.P.; Kuhl, P.K.; Meltzoff, A.N.; Stevens, E.B. (1991). *Integrating Speech Information across Talkers, Gender and Sensory Modality: Female Faces and Male Voices in the McGurk Effect*. Percept. Psychophys., Vol. 50:524-536.

852. Gregory, R.L. (1987). Ed. *The Oxford Companion to the Mind.* Oxford University Press.

853. Grobstein, P. (1991). *Directed Movement in the Frog: A Closer Look at a Central Representation of Spatial Location.* In: M.A. Arbib, J.-P. Ewert, Eds., Visual Structure and Integrated Functions, Pp.125-138. Springer-Verlag.

854. Groeger, J.A. (1997). *Memory and Remembering: Everyday Memory in Context.* Addison Wesley Longman, London.

855. Grossberg, S. (1976). *Adaptive Pattern Classification and Universal Recoding: Parallel Development and Coding of Neural Feature Detectors*. Biological Cybernetics, Vol. 23:121-134. (Reprinted in Anderson and Rosenfeld, 1988).

856. Grossberg, S. (1976). *Adaptive Pattern Classification and Universal Recoding, 11: Feedback, Expectation, Olfaction and Illusions.* Biol. Cybern., Vol. 23:187-202.

857. Grossberg, S. (1980). *How does a Brain build a Cognitive Code?* Psych. Rev., Vol. 1:1-51.

858. Grossberg, S. (1982). *Studies of Mind and Brain.* Kluwer.

859. Grossberg, S. (1982). *Studies of Mind and Brain: Neural Principles of Learning, Perception, Development, Cognition and Motor Control.* Reidel Press, Boston.

860. Grossberg, S. (1987). *The Adaptive Brain, Vol. II.* Elsevier/North-Holland.

861. Grossberg, S. (1999a). *The Link between Brain Learning, Attention and Consciousness.* Consciousness and Cognition, Vol. 8:1-44.

862. Grossberg, S. (1999b). *How does the Cerebral Cortex Work? Learning, Attention, and Grouping by the Laminar Circuits of Visual Cortex.* Spatial Vision, Vol. 12:163-187.

863. Grossberg, S. (2000). *The Complementary Brain: Unifying Brain Dynamics and Modularity.* Trends in Cognitive Sciences, Vol. 4 No. 6:233-246.

864. Grossberg, S., Ed., (1987a). *The Adaptive Brain, I: Cognition, Learning, Reinforcement and Rhythm.* Elsevier/North-Holland, Amsterdam.

865. Grossberg, S., Ed., (1987b). *The Adaptive Brain, II: Vision, Speech, Language and Motor Control.* Elsevier/North-Holland, Amsterdam.

866. Grossberg, S., Ed., (1988). *Neural Networks and Natural Intelligence.* MIT Press, Cambridge, MA.

867. Grossberg, S.; Boardman, I.; Cohen, M.A. (1997). *Neural Dynamics of Variable-Rate Speech Categorization.* In: Human Percept and Perform, J. Exptal. Psychol., Vol. 23:481-503.

868. Grossberg, S.; Grunewald, A. (1997). *Cortical Synchronization and Perceptual Framing.* J. Cognitive Neurosci., Vol. 9:117-132.

869. Grossberg, S.; Merrill, J.W.L. (1992). *A Neural Network Model of Adaptively Timed Reinforcement Learning and Hippocampal Dynamics.* Cog. Brain Res., Vol. 1:3-38.

870. Grossberg, S.; Merrill, J.W.L. (1996). *The Hippocampus and Cerebellum in Adaptively Timed Learning, Recognition and Movement.* J. Cognitive Neurosci., Vol. 8:257-277.

871. Grossberg, S.; Mingolla, E.; Pack, C. (1999). *A neural Model of Motion Processing and Visual Navigation by Cortical Area MST.* Cerebral Cortex, Vol. 9:878-895.

872. Grossberg, S.; Mingolla, E.; Ross, W.D. (1997). *Visual Brain and Visual Perception: How does the Cortex do Perceptual Grouping?* Trends in Neurosci., Vol. 20:106-111.

873. Grossberg, S.; Myers, C. (1999). *The Resonant Dynamics of Speech Perception: Interword Integration and Duration-Dependent Backwards Effects.* Psychol. Rev. In Press.

874. Grossberg, S.; Raizada, R. (2000). *Contrast-Sensitive Perceptual Grouping and Object-Based Attention in the Laminar Circuits of Primary Visual Cortex.* Vision Res. In Press.

875. Grossberg, S.; Todorovic, D. (1988). *Neural Dynamics of 1-D and 2-D Brightness Perception: A Unified Model of Classical and Recent Phenomena.* Percept. And Psychophys., Vol. 43:723-742.

876. Gu, Q.; Kiu, Y.; Cynader, M.S. (1994). *Nerve Growth Factor-induced Ocular Dominance Plasticity in Adult Cat Visual Cortex*. Proc. Natl. Acad. Sci., Vol. 91:8408-8412. USA.

877. Guare, J. (1990). *Six Degrees of Separation.* Random House, New York.

878. Guenther, F.H.; Bullock, D.; Greve, D.; Grossberg, S. (1994). *Neural Representations for Sensory-Motor Control, III: Learning a Body-Centered Representation of 3-D Target Position.* J. Cognit. Neurosci., Vol. 6:341-358.

879. Hagman, J.O.; Wood, F.; Buchsbaum, M.S.; Tallal, P.; Flowers, L.; Katz, W. *Cerebral Brain Metabolism in Adult Dyslexia Subjects assessed with Positron Emission Tomography during Performance of an Auditory Task.* Arch. Neurol., Vol. 49:734-739.

880. Hamann, S.B.; et al. (1999). *Amygdala Activity Related to Enhanced Memory for Pleasant and Aversive Stimuli.* Nat. Neurosci., Vol. 2:289-293.

881. Hampson, E. (1990a). *Estrogen-related Variations in Human Spatial and Articulatory-motor Skills*. Psychoneuroendocrinology, Vol. 15:97-111.

882. Hampson, E. (1990b). *Variations in Sex-related Cognitive Abilities across the Menstrual Cycle*. Brain Cogn., Vol. 14:26-43.

883. Hare, M.; Elman, J.L.; Daugherty, K.G. (1995). *Default Generalization in Connectionist Networks.* Language and Cognitive Processes, Vol. 10:601-630.

884. Harth, E. (1997). *From Brains to Neural Nets to Brains.* Neural Networks, Vol. 10:1241-1255.

885. Hawkins, R.D.; Kandel, E.R.; Siegelbaum, S.A. (1993). *Learning to modulate Transmitter Release: Themes and Variations in Synaptic Plasticity*. Annu. Rev. Neurosci., Vol. 16:625-665.

886. Hebb, D.O. (1949). *The Organisation of Behaviour*. Wiley, New York.

887. Heeger, D.J. (1993). *Modeling Simple-Cell Direction Selectivity with Normalized, Half-Squared Linear Operators.* J. Neurophysiol., Vol. 70:1885-1898.

888. Hendry, S.H.; Huntsman, M.M.; Vinuela, A.; Mohler, H.; De Blas, A.; Jones, E.G. (1994). *$GABA_A$ Receptor Subunit Immunoreactivity in Primate Visual Cortex: Distribution in Macaques and Humans and Regulation by Visual Input in Adulthood.* J. Neurosci., Vol. 14:2383-2401.

889. Hertz, J.; Krogh, A.; Palmer, R. (1991). *Introduction to the Theory of Neural Computation.* Addison-Wesley, Redwood, CA.

890. Hinton, G.; Shallice, T. (1991). *Lesioning an Attractor Network: Investigations of Acquired Dyslexia*. Psychological Review, Vol. 98:74-95.

891. Hinton, G.E.; Anderson, J.A. (1981). *Parallel Models of Associative Memory*. In: J.A. Anderson, Ed., Parallel Models of Associative Memory, 2nd Edition, 1989. Erlbaum, Hillsdale, NJ.

892. Holland, P.C.; Gallagher, M. (1999). *Amygdala Circuitry in Attentional and Representational Processes.* Trends Cognit. Sci., Vol. 3:65-73.

893. Horak, F.B.; Anderson, M.E. (1984). *Influence of Globus Pallidus on Arm Movements in Monkeys. I. Effects of Kainic Acid-Induced Lesions.* J. Neurophysiol., Vol. 52:290-322.

894. Huerta, P.T.; Lisman, J.E. (1995). *Bi-directional Synaptic Plasticity induced by a Single Burst during Cholinergic Theta Oscillation in CA1 in vitro.* Neuron, Vol. 15:1053-1063.

895. Hummel, J.E.; Biederman, I. (1992). *Dynamic Binding in a Neural Network for Shape Recognition*. Psychol. Rev., Vol. 99:480-517.

896. Huntsman, M.M.; Leggio, M.G.; Jones, E.G. (1995). *Expression Patterns and Deprivation Effects on $GABA_A$ Receptor Subunit and GAD mRNAs in Monkey Lateral Geniculate Nucleus.* J. Comp. Neurol., Vol. 352:235-247.

897. Hupé, J.M.; James, A.C.; Payne, B.R.; Lomber, S.G.; Girard, P.; Bullier, J. (1998). *Cortical Feedback improves Discrimination between Figure and Background by V1, V2 and V3 Neurons.* Nature, Vol. 394:784-787.

898. Imamizu, H.; Miyauchi, S.; Sasaki, Y.; Takino, R.; Pütz, B.; Kawato, M. (1997). *Separated Modules for Visuomotor Control and Learning in the Cerebellum: A Functional MRI Study.* NeuroImage, Vol. 5:S598.

899. Inhelder, B.; Piaget, J. (1958). *The Growth of Logical Thinking from Childhood to Adolescence.* Basic Books, New York.

900. Ito, M. (1984). *The Cerebellum and Neural Control.* Raven Press.

901. Ivry. R. (1993). *Cerebellar Involvement in the Explicit Representation of Temporal Information.* In: P. Tallal, A. Galaburda, R.R. Llinias, C. Von Euler, Eds., Temporal Information Processing in the Nervous System: Special Reference to Dyslexia and Dyshasia, Vol. 682:214-230. Annals New York Academy of Sciences, New York.

902. Ivry, R.B. (1996). *The Representation of Temporal Information in Perception and Motor Control*. Current Opinion in Neurobiology, Vol. 6:851-857.

903. Ivry, R. (1997). *The many Manifestations of a Cerebellar Timing System.* In: J. Schmahmann, Ed., The Cerebellum and Cognition. Academic Press, San Diego.

904. Izard, C.E. (1992). *Basic Emotions, Relations among Emotions and Emotion-cognition Relations.* Psychological Review, Vol. 99:561-565.

905. Jacobs, R.A.; Jordan, M.I.; Barto, A.G. (1991). *Task Decomposition though Competition in a Modular Connectionist Architecture: The What and Where Vision Tasks*. Cognitive Science, Vol. 15:219-250.

906. Jacobs, W.J.; Nadel, L. (1985). *Stress-induced Recovery of Fears and Phobias.* Psychological Review, Vol. 92:512-531.

907. Jacobson, L.; Sapolsky, R. (1991). *The Role of the Hippocampus in Feedback Regulation of the Hypothalamic-pituitary-adrenocortical Axis.* Endocrine Reviews, Vol. 12(2):118-134.

908. Jahanshahi, M.; Jenkins, I.H.; Brown, R.G.; Marsden, C.D.; Passingham, R.E.; Brooks, D.J. (1995). *Self-initiated versus externally triggered Movements. I. An Investigation using Measurement of Regional Cerebral Blood Flow with PET and Movement-related Potentials in normal and Parkinson's Disease Subjects*. Brain, Vol. 118:913-933.

909. James, W. (1884). *What is an Emotion?* Mind, Vol. 9,188-205.

910. Jeannerod, M.; Decety, J. (1995). *Mental Motor Imagery: A Window into the Representational Stages of Action*. Current Opinion in Neurobiology, Vol. 5:727-732.

911. Johansen-Berg, H. (2001). *Long-haul Brain Drain.* Trends in Cognitive Sciences, Vol. 5(7).

912. Johnson, M.H. (1993). *Brain Development and Cognition: A Reader*. Blackwell, Oxford.

913. Johnson, M.H. (1994). *Brain and Cognitive Development in Infancy*. Current Opinion in Neurobiology, Vol. 4:218-225.

914. Johnson, M.H. (1998). *The Development of Attention: A Cognitive Neuroscience Approach.* In: M.S. Gazzaniga, Ed., The Cognitive Neurosciences. MIT Press, Cambridge, MA.

915. Johnson-Laird, P.N. (1988). *The Computer and the Mind: An Introduction to Cognitive Science.* Harvard University Press, Cambridge.

916. Joliot, M.; Ribary, U.; Llinias R. *Human Oscillatory Brain Activity near 40Hz coexists with Cognitive Temporal Binding.* Proc. Natl. Acad. Sci., Vol. 91:11748-11751. USA.

917. Joyner, A.L. (1993). *Gene Targeting: A Practical Approach*. Oxford University Press, New York.

918. Kahneman, D.; Slovic, P.; Tversky, A. (1982). *Judgement under Uncertainty: Heuristics and Biases.* Cambridge University Press, Cambridge.

919. Kalaska, J.F.; Caminiti, R.; Georgopoulos, A.P. (1983). *Coritcal Mechanisms related to the Direction of Two-dimensional Arm Movements: Relation in Parietal Area 5 and Comparison with Motor Cortex*. Exp. Brain Res., Vol. 51:247-260.

920. Kamin, L.J. (1969). *Predictability, Surprise, Attention, and Conditioning.* In: B.A. Campbell, R.M. Church, Eds., Punishment and Aversive Behavior, Pp.279-298. Appleton Century Crofts.

921. Kanizsa, G. (1974). *Contours without Gradients or Cognitive Contours.* Italian J. Psychol., Vol. 1:93-113.

922. Kapadia, M.K.; Ito, M.; Gilbert, C.D.; Westheimer, G. (1995). *Improvement in Visual Sensitivity by Changes in Local Context: Prarllel Studies in Human Observers and in V1 of Alert Monkeys.* Neuron, Vol. 15:843-856.

923. Kapp, B.S.; Whalen, P.J.; Supple, W.F.; Pascoe, J.P. (1992). *Amygdaloid Contributions to Conditioned Arousal and Sensory Information Processing.* In: J.P. Aggleton, Ed., The Amygdala: Neurobiological Aspects of Emotion, Memory and Mental Disfunction. Wiley-Liss, New York.

924. Karmiloff-Smith, A. (1992). *Beyond Modularity: A Developmental Perspective on Cognitive Science*. MIT Press, Cambridge, MA.

925. Karni, A.; Meyer, G.; Jezzard, P.; Adams, M.M.; Turner, R.; Ingerleider, L.G. (1995). *Functional MRI Evidence for Adult Motor Cortex Plasticity during Motor Skill Learning.* Nature, Vol. 377:155-158.

926. Kawashima, R.; Itoh, H.; Ono, S.; Satoh, K.; Furumoto, S.; Gotoh, R.; Koyama, M.; Yoshioka, S.; Takahashi, T.; Takahashi, K. et al. (1996b). *Changes in Regional Cerebral Blood Flow during Self-paced Arm and Finger Movements. A PET Study*. Brain Res., Vol. 716:141-148.

927. Kawashima, R.; O'Sullivan, B.T.; Roland, P.E. (1994). *Fields in Human Motor Areas involved in Preparation for Reaching, Actual Reaching and Visuomotor Learning: A Positron Emission Tomography Study*. J. Neurosci., Vol. 14:3462-3474.

928. Kawashima, R.; Satoh, K.; Itoh, H.; Ono, S.; Furumoto, S.; Gotoh, R.; Koyama, M.; Yoshioka, S.; Takahashi, T.; Takahashi, K. et al. (1996a). *Functional Anatomy of GO/NO-GO Discrimination and Response Selection – a PET Study in Man*. Brain Res., Vol. 728:79-89.

929. Kesner, R.P.; Bolland, B.L.; Dakis, M. (1993). *Memory for Spatial Locations, Motor Responses and Objects: Triple Dissociation among the Hippocampus, Caudate Nucleus and Extrastriate Visual Cortex*. Exp. Brain Res., Vol. 45:147-161.

930. Kihlstrom, J.F. (1987). *The Cognitive Unconscious.* Science, Vol. 237:1445-1452.

931. Kimura, D. (1996). *Sex, Sexual Orientation and Sex hormones influence Human Cognitive Function*. Current Opinion in Neurobiology, Vol. 6:259-263.

932. Koch, C. (1998). *Biophysics of Computation: Information Processing in Single Neurons.* Oxford University Press.

933. Koch, C.; Zador, A.; Brown, T.H. (1992). *Dendritic Spines: Convergence of Theory and Experiment*. Science, Vol. 256:973-974.

934. Kohonen, T. (1984). *Self-organization and Associative Memory*. (2nd Edition 1988; 3rd Edition 1989) Springer-Verlag, Berlin.

935. Kohonen, T.; Hari, R. (1999). *Where the Abstract Feature Maps of the Brain Might Come From.* Trends Neurosci., Vol. 22:135-139.

936. König, P.; et al. (1996). *Integrator or Coincidence Detector? The Role of the Cortical Neuron revisited*. Trends Neurosci., Vol. 19:130-137.

937. Kosslyn, S.M.; Alpert, N.M.; Thompson, W.L.; Maljkovic, V.; Weise, S.B.; Chabris, C.F.; Hamilton, S.E.; Rauch, S.L.; Buonanno, F.S. (1993). *Visual Mental Imagery activates Topographically Organized Visual Cortex. PET Investigations*. J. Cogn. Neurosci., Vol. 5:263-287.

938. Kravitz, J.H.; Yaffe, F. (1972). *Conditioned Adaptation to Prismatic Displacement with a Tone as the Conditional Stimulus.* Perception and Psychophysics, Vol. 12:305-308.

939. Kreiter, A.K.; Singer, W. (1996). *Stimulus-dependent Synchronization of Neuronal Responses in the Visual Cortex of Awake Macaque Monkey*. Journal of Neuroscience, Vol. 16:2381-2396.

940. Kuhl, P.K. (1991). *Human Adults and Human Infants how a 'Perceptual Magnet Effect' for the Prototypes of Speech Categories, Monkeys do not*. Percept. Psychophys., Vol. 50:93-107.

941. Kuhl, P.K. (1994). *Learning and Representation in Speech and Language*. Current Opinion in Neurobiology, Vol. 4:812-822.

942. Kuhl, P.K.; Meltzoff, A.N. (1995a). *Evolution, Nativism and Learning in the Development of Lnaguage and Speech*. In: M. Gopnik, Ed., The Biological Basis of Language. Oxford University Press, New York.

943. Kuhl, P.K.; Meltzoff, A.N. (1995b). *Infant Vocalizations in Response to Speech: Vocal Imitation and Developmental Change*. J. Acoust. Soc. Am.

944. Kuhl, P.K.; Tsuzaki, M.; Tohkura, Y.; Meltzoff, A.N. (1994). *Human Processing of Auditory-visual Information in Speech Perception: Potential for Multimodal Human-machine Interfaces*. In: Proceedings of the International Conference on Spoken Language Processing, pp.539-542. The Acoustical Society of Japan, Kyoto.

945. LaBerge, D.L. (1995). *Attentional Processing: The Brain's Art of Mindfulness*. Harvard University Press, Cambridge, MA.

946. Laird, J.E.; Newell, A.; Rosenbloom, P.S. (1987). *Soar: An Architecture for General Intelligence*. Artif. Intell., Vol. 33:1-64.

947. Larsson, J.; Gulyàs, B.; Roland, P.E. (1996). *Cortical Representation of Self-paced Finger Movement*. Neuroreport, Vol. 7:463-468.

948. Lashley, K. (1950). *The Problem of Serial Order in Behaviour*. In: L.A. Jeffers, Ed., Cerebral Mechanisms in Behaviour. Wiley, New York.

949. LeDoux, J.E. (1993). *Emotional Memory Systems in the Brain.*. Behav. Brain Res., Vol. 58:69-79.

950. LeDoux, J.E. (1998). *The Emotional Brain: The Mysterious Underpinnings.* Touchstone, New York.

951. Leonard, C.M.; Voeller, K.K.S.; Lombardino, L.J.; Morris, M.K.; Hynd, G.W.; Alexander, A.W.; Andersen, H.G.; Garofalakis, M.; Honeyman, J.C.; Mao, J. et al. (1993). *Anomalous Cerebral Structure in Dyslexia revealed with Magnetic Resonance Imaging.* Arch. Neurol., Vol. 50:461-469.

952. Leopold, D.A.; Logothetis, N.K. (1999). *Multistable Phenomena: Changing Views in Perception*. Trends Cognit. Sci., Vol. 3:254-264.

953. Leslie, A. (1987). *Pretense and Representation: The Origin of 'Theory of Mind'.* Psychol. Rev., Vol. 94:412-426.

954. Levenson, R.W. (1992). *Autonomic Nervous System Differences among Emotions.* Psychological Science, Vol. 3:23-27.

955. Livingstone, M.S. (1996). *Oscillatory Firing and Interneuronal Correlations in Squirrel Monkey Striate Cortex*. J. Neurophysiol., Vol. 75:2467-2485.

956. Llinás, R.; Ribary, U. (1993). *Coherent 40Hz Oscillation Characteristics Dream States in Humans*. Proc. Natl. Acad. Sci. (U.S.A.), Vol. 90:2078-2081.

957. Llinás, R.; Ribary. U. (1994). *Perception as an Oneiric-like State modulated by the Senses.* In; C. Koch, J. Davis, Eds., Large-scale Neuronal Theories of the Brain, pp.111-124. MIT Press.

958. Llinas, R.R., Pare, D. (I1991). *Commentary: of Dreaming and Wakefulness*. Neuroscience, Vol. 44(3):521-535.

959. Llinas, R.R., Ribary, U., Joliot, M., Wang, X-J. (1994). *Content and Context in Temporal Thalamo-cortical Binding*. In: G. Busaki et al, Eds., Temporal Coding in the Brain, pp.251-272. Springer-Verlag, Heidelberg.

960. Luck, S.J.; Chelazzi, L.; Hillyard, S.A.; Desimone, R. (1997). *Neural Mechanisms of Spatial Selective Attention in Areas V1, V2 and V4 of Macaque Visual Cortex.* J. Neurophysiol., Vol. 77:24-42.

961. Lund, J.; Yoshioka, T.; Levitt, J. (1993). *Comparison of Intrinsic Connectivity in different Areas of Macaque Monkey Cerebral Cortex*. Cereb. Cortex, Vol. 3:148-162.

962. Mareschal, D.; Plunkett, K.; Harris, P. (1995). *Developing Object Permanence: A Connectionist Model*. In: J. Moore and J. Lehman, Eds., Proceedings of the Seventeenth Annual Conference of the Cognitive Science Society, pp.170-175. Erlbaum, Mahwah, NJ.

963. Markram, H.; et al. (1997). *Regulation of Synaptic Efficacy by Coincidence of Postsynaptic APs and EPSPs*. Science, Vol. 275:213-215.

964. Martin, T.A.; Keating, J.G.; Goodkin, H.P.; Bastian, A.J.; Thach, W.T. (1996). *Throwing while looking through Prisms, II: Specificity and Storage of Multiple Gaze Throw Calibrations.* Brain, Vol. 119:1199-1211.

965. Matelli, M.; Rizzolatti, G.; Bettinardi, V.; Gilardi, M.C.; Perani, D.; Rizzo, G.; Fazio, F. (1993). *Activation of Precentral and Mesial Motor Areas during the Execution of Elementary Proximal and Distal Arm Movements: A PET Study*. Neuroreport, Vol. 4:1295-1298.

966. Mayford, M.; Abel, T.; Kandel, E.R. (1995). *Transgenic Approaches to Cognition*. Current Opinion in Neurobiology, Vol. 5:141-148.

967. McClelland, J.L. (1986). *The Programmable Blackboard Model of Reading.* In: J.L. McClelland and D.E. Rumelhart, Eds., Parallel Distributing Processing, Vol. 2:122-169. MIT Press.

968. McClelland, J.L. (1989). *Parallel Distributed Processing: Implications for Cognition and Development*. In: R Morris, Ed., Parallel Distributed Processing: Implications for Psychology and Neurobiology. Claredon Press, Oxford.

969. McClelland, J.L.; Rumelhart, D. (1986). *Parallel Distributed Processing.* MIT Press, Cambridge, MA.

970. McCormick, D.A.; Bal, T. (1994). *Sensory Gating Mechanisms of the Thalamus.* Current Opinion in Neurobiology, Vol. 4:550-556.

971. McCulloch, W.; Pitts, W. (1943). *A Logical Calculus of the Ideas Immanent in Nervous Activity.* Bulletin of Mathematical Biophysics, Vol. 5:115-133. (Reprinted in Anderson and Rosenfeld, 1988).

972. McEwen, B.S. (1992). *Paradoxical Effects of Adrenal Steroids on the Brain: Protection versus Degeneration.* Biological Psychiatry, Vol. 31:177-199.

973. McEven, B.S.; Sapolsky, R.M. (1995). *Stress and Cognitive Function.* Current Opinion in Neurobiology, Vol. 5:205-216.

974. McGaugh, J.L.; Cahill, L.; Parent, M.B.; Mesches, M.H.; Coleman-Mesches, K.; Salinas, J.A. (1995). *Involvement of the Amygdala in the Regulation of Memory Storage.* In: J.L. McGaugh, F. Bermudez-Rattoni, R.A. Prado-Alcala, Eds., Plasticity in the Central Nervous System: Learning and Memory. Erlbaum, Hillsdale, NJ.

975. McLeod, P.; Plunkett, K.; Rolls, E.T. (1998). *Introduction to Connectionist Modelling of Cognitive Processes.* Oxford University Press.

976. Mealey, L.; Daood, C.; Krage, M. (1996). *Enhanced Memory for Faces of Cheaters.* Ethol. Sociobiol., Vol. 17:119-128.

977. Mehler, J. (1981). *The Role of Syllables in Speech Perception: Infant and Adult Data*. Philos. Trans. R. Soc. Lond. (Biol), Vol. 295:333-352.

978. Mehler, J.; Dommergues, J.Y.; Frauenfelder, U.; Segui, J. (1981). *The Syllable's Role in Speech Segmentation*. J. Verbal Learn Verbal Behav., Vol. 20:298-305.

979. Mehler, J.; Dupoux, E.; Pallier, C.; Dehaene-Lambertz, G. (1994). *Cross-linguistic Approaches to Speech Processing*. Current Opinion in Neurobiology, Vol. 4:171-176.

980. Mehler, J.; Jucszyk, P.W.; Lambertz, G.; Halsted, N.; Bertoncini, J.; Amiel-Tison, C. (1988). *A Precursor of Language Acquisition in Young Infants*. Cognition, Vol. 29:143-178.

981. Mel, B.W. (1994). *Information Processing in Dendritic Trees*. Neural Computation, Vol. 6:1031-1085.

982. Meltzoff, A.N.; Moore, M.K. (1977). *Imitation of Facial and Manual Gestures by Human Neonates.* Scince, Vol. 198:74-78.

983. Metzinger, T. (1995). *Faster than Thought. Holism, Homogeneity and Temporal Binding*. In: T. Metzinger, Ed., Conscious Experience, pp.425-461. Schöningh.

984. Meunier, M.; et al. (1996). *Effects of Aspiration vs Neurotoxic Lesions of the Amygdala on Emotional Reactivity in Rhesus Monkeys.* Soc. Neuroaci. Abstr., Vol. 22:1867.

985. Miall, R.C.; Weir, D.J.; Wolpert, D.M.; Stein, J.F. (1993). *Is the Cerebellum a Smith Predictor?* J. Motor Behav., Vol. 25(3):203-216.

986. Miller, J.L. (1994). *On Internal Structure of Phonetic Categories: A Progress Report*. Cognition, Vol. 50:271-285.

987. Miller, S.L.; Delaney, T.V.; Tallal, P. (1995). *Speech and other Central Auditory Processes: Insights from Cognitive Neuroscience*. Current Opinion in Neurobiology, Vol. 5:198-204.

988. Mineka, S.; Davidson, M.; Cook, M.; Keir, R. (1984). *Observational Conditioning of Snake Fear in Rhesus Monkeys.* Journal of Abnormal Psychology, Vol. 93:355-372.

989. Minsky, M.; Papert, S. (1969). *Perceptrons*. MIT Press, Cmbridge MA.

990. Mishkin, M.; Ungerleider, L.G.; Macko, K.A. (1983). *Object Vision and Spatial Vision: Two Cortical Pathways.* Trends in Neurosci., Vol. 6:414-417.

991. Moffitt, T.E.; Caspi, A.; Dickson, N.; Silva, P.; Stanton, W. (1996). *Childhood-Onset versus Adolescent-Onset Antisocial Conduct Problems in Males: Natural History from Ages 3 to 18 Years.* Development and Psychopathology, Vol. 8:399-424.

992. Mogilner, A.; Grossman, J.A.; Ribary, U.; Joliot, M.; Volkmann, J.; Rapaport, D.; Beasley, R.W.; Llinias, R.R. (1993). *Somatosensory Cortical Plasticity in Adult Humans revealed by Magnetoencephalography*. Proc. Natl. Sci., Vol. 90:3593-3597. USA.

993. Mollon, J.D.; Sharpe, L.T. (1983). *Colour Vision.* Academic Press.

994. Motter, B.C. (1993). *Focal Attention produces Apstially Selective Processing in Visual Cortical Areas' V1, V2 and V4 in the Presence of Competing Stimuli.* J. Neurophysiol., Vol. 70:909-919.

995. Motter, B.C. (1994a). *Neural Correlates of Attentive Selective Memory and Pop-Out in Extrastriate Area V4.* J. Neurosci., Vol. 14:2178-2189.

996. Motter, B.C. (1994b). *Neural Correlates of Attentive Selective Memory and Pop-Out in Extrastriate Area V4.* J. Neurosci., Vol. 14:2190-2199.

997. Munk, M.H.J.; et al. (1996). *Role of Reticular Activation in the Modulation of Intra-cortical Synchronization*. Science, Vol. 272:271-274.

998. Murthy, V.N.; Fetz, E.E. (1992). *Coherent 25-to 35-Hz Oscillations in the Sensorimotor Cortex of Awake Behaving Monkeys*. Proc. Natl. Acad. Sci. (U.S.A.), Vol. 89:5670-5674.

999. Nadel, L.; Willner, J. (1980). *Context and Conditioning: A Place for Space.* Physiological Psychology, Vol. 8:218-228.

1000. Nakisa, R.C.; Plunkett, K. (1998). *Evolution of a Rapidly Learned Representation for Speech.* Language and Cognitive Processes. (In Press)

1001. Neisser, U. (1976). *Cognition and Reality*. Freeman, San Francisco.

1002. Nelson, C.A.; Deregnier, R.A. (1992). *Neural Correlates of Attention and Memory in the First Year of Life*. Dev. Neuropsychol., Vol. 8:119-134.

1003. Neville, H.J.; Coffey, S.A.; Holcomb, P.J.; Tallal, P. (1993). *The Neurobiology of Sensory and Language Processing in Language-impaired Children*. J. Cogn. Neurosci., Vol. 5:235-253.

1004. Newell, A. (1989). *Unified Theories of Cognition.* Harvard University Press, Cambridge, MA.

1005. Newell, A.; Simon, H.A. (1972). *Human Problem Solving.* Prentice-Hall, Englewood Cliffs, NJ.

1006. Newman, J. (1997). *Putting the Puzzle together: Towards a General Theory of the Neural Correlates of Consciousness.* Journal of Consciousness Studies, Vol. 4(1 and 2):47-66 and 99-120.

1007. Newman, J., Baars, B.J. (1993). *A Neural Attentional Model for Access to Consciousness: A Global Workspace Perspective.* Concepts in Neuroscience, Vol. 4(2):255-290.

1008. Newman, J., Baars, B.J., Cho, S-B. (1997). *A Neural Global Workspace Model for Conscious Attention.* Neural Networks, Vol. 10(7):1195-1206. Elsevier Science Ltd., Great Britain.

1009. Niebur, E.; et al. (1993). *An Oscillation-based Model for the Neuronal Basis of Attention.* Vis. Res., Vol. 33:2789-2802.

1010. Nisbett, R.E.; Wilson, T.D. (1977). *Telling more than we can know: Verbal Reports on Mental Processes.* Psychological Review, Vol. 84:231-259.

1011. Nolfi, S.; Elman, J.; Parisi, D. (1994). *Learning and Evolution in Neural Networks.* Adaptive Behaviour, Vol. 3:5-28.

1012. Nosofsky, R.M. (1988). *Exemplar-based Accounts of Relations between Classification, Recognition and Typicality.* J. Exp. Psych: Learn. Mem. Cog., Vol. 14:700-708.

1013. O'Keefe, J.; Nadel, L. (1978). *The Hippocampus as a Cognitive Map.* Clarendon Press, Oxford.

1014. O'Leary, D.D.M.; Ruff, N.L.; Dyck, R.H. (1994). *Development, Critical Period Plasticity and Adult Reorganizations of Mammalian Somatosensory Systems.* Current Opinion in Neurobiology, Vol. 4:535-544.

1015. Otto, T.; Eichenbaum, H. (1992). *Neuronal Activity in the Hippocampus during Delayed Non-Match to sample Performance in Rats: Evidence for Hippocampal Processing in Recognition Memory.* Hippocampus, Vol. 2:323-334.

1016. Pack, C.; Grossberg, S.; Mingolla, E. (1999). *A Neural Model of Smooth Pursuit Control and Motion Perception by Cortical Area MST.* Boston U. Tech. Report 99-023.

1017. Parthasarathy, H.B.; Schall, J.D.; Graybiel, A.M. (1992). *Distributed but Convergent Ordering of Striatal Projections: The Frontal Eye Field and the Supplementary Eye Field in the Monkey.* J. Neurosci., Vol. 12:4468-4488.

1018. Pascual-Lenon, A.; Grafman, J.; Hallett, M. (1994). *Modulation of Cortical Motor Output Maps during Development of Implicit and Explicit Knowledge.* Science, Vol. 263:1287-1289.

1019. Pavlov, I.P. (1927). *Conditioned Reflexes.* Oxford University Press.

1020. Penfield, W.; Boldrey, E. (1937). *Somatic Motor and Sensory Representation in the Cerebral Cortex of Man as studied by Electrical Stimulation*. Brain, Vol. 60:389-443.

1021. Perner, J.; Lang, B. (1999). *Development of Theory of Mind and Executive Control.* Trends Cognit. Sci., Vol. 3:337-344.

1022. Perrett, D.I.; Smith, P.A.J.; Potter, D.D.; Mistlin, A.J.; Head, A.S.; milner, A.D.; Jeeves, M.A. (1984). *Neurones responsive to Faces in the Temporal Cortex*. Hum. Neurobiol., Vol. 3:197-208.

1023. Perrett, S.P.; Ruiz, B.P.; Mauk,M.D. (1993). *Cerebellar Cortex Lesions disrupt Learning-Dependent Timing of Conditioned Eye-Lid Responses.* Journal of Neuroscience, Vol. 13:1708-1718.

1024. Perrig, W.; Kintsch, W. (1985). *Propositional and Situational Representations of Text.* Journal of Memory and Language, Vol. 24:503-518.

1025. Pessoa, L.; Beck, J.; Mingolla, E. (1996). *Perceived Texture Segregation in Chromatic Element-Arrangement Patterns: High Intensity Interference.* Vision Res., Vol. 36:1745-1760.

1026. Pettito, L.A.; Marentette, P.F. (1991). *Babbling in the Manual Mode: Evidence for the Ontogeny of Language*. Science, Vol. 251:1493-1496.

1027. Phillips, W.A. (2001). *Synchronization: Making Sense of the Data.* Trends in Cognitive Sciences, Vol. 5(7).

1028. Piaget, J. (1954). *The Construction of Reality in the Child*. Basic Books, New York.

1029. Pinker, S. (1994). *The Language Instinct: How the Mind creates Language.* Morrow, New York.

1030. Pinker, S.; Prince, A. (1988). *On Language and Connectionism: Analysis of a Parallel Distributed Processing Model of Language Acquisition.* Cognition, Vol. 28:73-193.

1031. Pisoni, D.B. (1993). *Long-term Memory in Speech Perception: Some new Findings on Talker Variability, Speaking Rate and Perceptual Learning*. Speech Comm., Vol. 13:109-125.

1032. Plaut, D.; McClelland, J.; Seidenberg, M.; Patterson, K. (1996). *Understanding Normal and Impaired Reading: Computational Principles in Quasi-regular Domains.* Psychological Review, Vol. 103:56-115.

1033. Plaut, D.; Shallice, T. (1993). *Deep Dyslexia: A Case Study of Connectionist Neuropsychology*. Cognitive Neuropsychology, Vol. 10:377-500.

1034. Plunkett, K.; Marchman, V.A. (1993). *From Rote Learning to System Building: Acquiring Verb Morphology in Children and Connectionist Nets*. Cognition, Vol. 48:21-69.

1035. Plunkett, K.; Marchman, V.A. (1996). *Learning from a Connectionist Model of the Acquisition of the English Past Tense*. Cognition, Vol. 61:299-308.

1036. Plunkett, K.; Sinha, C.; Muller, M.F.; Strandsby, O. (1992). *Symbol Grounding or the Emergence of Symbols? Vocabulary Growth in Children and a Connectionist Net.* Connection Science, Vol. 4:293-312.

1037. Poeppel, E. (1996). *Reconstruction of Subjective Time on the Basis of Hierarchically Organized Processing System.* In: M.A. Pastor, J. Artieda, Eds.,Time, Internal Clocks and Movement, pp.165-185. New York.

1038. Posner, M. (1992). *Attention as a Cognitive and Neural System.* Current Directions in Psychological Science, Vol. 1:11-14.

1039. Potegal, M. (1969). *Role of the Caudate Nucleus in Spatial Orientation of Rats.* J. Comp. Physiol. Psychol., Vol. 69:756-764.

1040. Premack, D.; Woodruff, G. (1978). *Does the Chimpanzee have a Theory of Mind?* Behav. Brain Sci., Vol. 1:515-526.

1041. Preuss, T.M. (1995). *Do Rats have Prefrontal Cortex? The Rose-Woolsey-Akert Program Reconsidered.* Journal of Cognitive Neuroscience, Vol. 7:1-24.

1042. Pulvermüller, F. (1999). *Words in the Brain's Language*. Behav. Brain Sci., Vol. 22:253-336.

1043. Putnam, H. (1960). *Minds and Machines.* In: S. Hook, Ed., Dimensions of Mind. Collier, New York.

1044. Quartz, S.R.; Sejnowski, T.J. (1997). *The Neural Basis of Cognitive Development: A Constructive Manifesto*. Behavioural and Brain Sciences. (In Press)

1045. Rager, G.; Singer, W. (1998). *The Response of Cat Visual Cortex to Flicker Stimuli of Variable Frequency*. Eur. Journal of Neurosci., Vol. 10:1856-1877.

1046. Rajkowska, G.; Goldman-Rakic, P. (1995). *Cytoarchitectonic Definition of Prefrontal Areas in the Normal Human Cortex. II. Variability in Locations of Areas 9 and 46 and Relationship to the Talairach Coordinate System*. Cereb. Cortex, Vol. 5:323-337.

1047. Raleigh, M.J.; et al. (1996). *Neural Mechanisms supporting Successful Social Decisions in Simians.* In: Y. Christen, A. Damasio, H. Damasio, Eds., Neurobiology of Decision Making, Pp.63-82. Springer-Verlag.

1048. Rao, S.M.; Binder, J.R.; Bandettini, P.A.; Hammecke, T.A.; Yetkin, F.Z.; Jesmanowicz, A.; Lisk, L.M.; Morris, G.L.; Mueller, W.M.; Estkowski, L.D. et al. (1993). *Functional magnetic Resonance Imaging of complex Human Movements*. Neurology, Vol. 43:2311-2318.

1049. Remy, P.; Zilbovicius, M.; Leroy-Willig, A.; Syrota, A.; Samson, Y. (1994). *Movement- and Task-related Activations of Motor Cortical Areas: A Positron Emission Tomographic Study.* Ann. Neurol., Vol. 36:19-26.

1050. Reynolds, J.; Desimone, R. (1999). *The Role of Mechanisms of Attention in Solving the Binding Problem*. Neuron, Vol. 24:19-29.

1051. Reynolds, J.; Nicholas, J.; Chelazzi, L.; Desimone, R. (1995). *Spatial Attention protects Macaque V2 and V4 Cells from the Influence of Non-Attended Stimuli.* Soc. For Neurosi. Abstracts, Vol. 21(3):1759.

1052. Reynolds, J.; Nicholas, J.; Chelazzi, L.; Desimone, R. (1999). *Competitive Mechanisms subserve Attention in Macaque Areas V2 and V4.* J. Neurosci., Vol. 19:1736-1753.

1053. Rieke, F.; Warland, D.; Bialek, W. (1999). *Spikes: Exploring the Neural Code.* MIT Press.

1054. Robinson, F.R. (1995). *Role of the Cerebellum in Movement Control and Adaptation.* Current Opinion in Neurobiology, Vol. 5:755-762.

1055. Roelfsema, P.R.; et al. (1996). *The Role of Neuronal Synchronization in Response Selection: A Biologically Plausible Theory of Structured Representation in the Visual Cortex*. Journal of Cognitive Neuroscience, Vol. 8:603-625.

1056. Roelfsema, P.R.; Lamme, V.A.F.; Spekreijse, H. (1998). *Object-Based Attention in the Visual Cortex of the Macaque Monkey.* Nature, Vol. 395:376-381.

1057. Roland, P.E.; Zilles, K. (1994). *Brain Atlases – A New Research Tool*. Trends Neurosci., Vol. 17:458-467.

1058. Roland, P.E.; Zilles, K. (1996). *Functions and Structures of the Motor Cortices in Humans*. Current Opinion in Neurobiology, Vol. 6:773-781.

1059. Rolls, E.T.; Treves, A. (1998). *Neural Networks and Brain Function*. Oxford University Press, Oxford.

1060. Rorty, A.O. (1980). *Explaining Emotions.* In: A.O. Rorty, Ed., Explaining Emotions. University of California Press, Berkeley.

1061. Rosch, E. (1975). *Cognitive Representations of Semantic Categories*. Journal of Experimental Psychology: General, Vol. 104:192-223.

1062. Rosenblatt, F. (1958). *The Perceptron: A probabilistic Model for Information Storage and Organisation in the Brain*. Psychological Review, Vol. 65:386-408. (Reprinted in Anderson and Rosenfeld, 1988).

1063. Rosenblatt, F. (1962). *Principles of Neurodynamics*. Spartan, New York.

1064. Rovee-Collier, C. (1993). *The Capacity for Long-Term Memory in Infancy*. Current Dir. Psychol., Vol. 2:130-135.

1065. Rumsey, J.M.; Andreason, P.; Zametkin, A.J.; Aquino, T.; King, A.C.; Hamburger, S.D.; Pikus, A.; Rapaport, J.L.; Cohen, R.M. (1992). *Failure to activate the left Temporoparietal Cortex in Dyslexia*. Arch. Neurol., Vol. 49:527-534.

1066. Sakata, H.; Shibutani, H.; Kawano, K. (1980). *Spatial Properties of Visual Fixation Neurons in Posterior Parietal Association Cortex of the Monkey.* J. Neurophysiol., Vol. 43:1654-1672.

1067. Sakata, H.; Shibutani, H.; Kawano, K.; Harrington, T.L. (1985). *Neural Mechanisms of Space Vision in the Parietal Association Cortex of the Monkey*. Vision Res., Vol. 25:453-463.

1068. Sakata, H.; Taira, M. (1994). *Parietal Control of Hand Action*. Current Opinion in Neurobiology, Vol. 4:847-856.

1069. Saleem, K.; Rockland, K.; Tanaka, K. (1993). *Specific and Columnar Projection from Area TEO to TE in the Macaque Inferotemporal Cortex*. Cereb. Cortex, Vol. 3:454-464.

1070. Salzman, C.D.; Newsome, W.T. (1994). *Neural Mechanisms for Forming a Perceptual Decision*. Science, Vol. 264:231-237.

1071. Sanes, J.N.; Donoghue, J.P.; Thangaraj, T.; Edelman, R.R.; Warach, S. (1995). *Shared Neural Substrates controlling Hand Movements in Human Motor Cortex*. Science, Vol. 268:1775-1777.

1072. Santosh, C.G.; Rimmington, J.E.; Best, J.J.K. (1995). *Functional Magnetic Resonance Imaging at 1 T: Motor Cortex, Supplementary Motor Area and Visual Cortex Activation*. Br. J. Radiol., Vol. 68:369-374.

1073. Sarnthein, J.; et al. (1998). *Synchronization between Prefrontal and Posterior Association during Human Working Memory*. Proc. Natl. Acad. Aci. (U.S.A.), Vol. 95:7092-7096.

1074. Scheibel, A.B. (1980). *Anatomical and Physiological Substrates of Arousal: A View from the Bridge*. In: J.A. Hobson, M.A.B. Brazier, Eds., The Reticular Formation revisited, pp.55-66. Raven Press, New York.

1075. Scherer, K.R. (1993a). *Neuroscience Projections to current Debates in Emotion Psychology.* Cognition and Emotion, Vol. 7:1-41.

1076. Scherer, K.R. (1993b). *Studying the Emotion-antecedent Appraisal Process: An Expert System Approach.* Cognition and Emotion, Vol. 7:325-355.

1077. Schlaug, G.; Knorr, U.; Seitz, R.J. (1994). *Inter-subject Variability of Cerebral Activations in acquiring a Motor Skill: A Study with Positron Emission Tomography*. Exp. Brain Res., Vol. 98:523-534.

1078. Schoenbaum, G.; Chiba, A.A.; Gallagher, M. (1998). *Orbitofrontal Cortex and Basolateral Amygdala Encode Expected Outcomes during Learning.* Nat. Neurosci., Vol. 1:155-159.

1079. Schore, A.N. (1999). *Affect Regulation and the Origin of the Self: The Neurobiology of Emotional Development.* Lawrence Erlbaum Assoc.

1080. Schwartz, A.B. (1994). *Distributed Motor Processing in Cerebral Cortex*. Current Opinion in Neurobiology, Vol. 4:840-846.

1081. Searle, J. (1980). *Minds, Brains, and Programs.* Behavioral and Brain Sciences, Vol. 3:417-458.

1082. Segui, J. (1984). *A Basic Perceptual Unit in Speech Processing?* In: H. Bouma, D.G. Bouwhuis, Eds., Attention and Performance : Control of Lnaguage Processes, pp.165-181. Erlbaum, Hillsdale, NJ.

1083. Seidenberg, M.; McClelland, J. (1989). *A Distributed Model of Word Recognition and Naming.* Psychological Review, Vol. 96:523-568.

1084. Seitz, R.J.; Roland, P.E. (1992). *Learning of Sequential Finger Movements in Man – A combined Kinematic and Positron Emission Tomography (PET) Study*. Eur. J. Neurosci., Vol. 4:154-165.

1085. Sekiyama, K.; Tohkura, Y. (1993). *Inter-language Differences in the Influence of Visual Cues in Speech Perception*. J. Phonets., Vol. 21:427-444.

1086. Shadlen M.N.; Newsome, W.T. (1994). *Noise, Neural Codes and Cortical Organization.* Current Opinion in Neurobiology, Vol. 4:569-579.

1087. Shadlen, M.N.; Movshon, J.A. (1999). *Synchrony unbound: A Critical Evaluation of the Temporal Binding Hypothesis.* Neuron, Vol. 24:67-77.

1088. Shallice, T. (1988). *From Neuropsychology to Mental Structure*. Cambridge University Press, Cambridge.

1089. Shastri, L.; Ajjanagadde, V. (1993). *From Simple Associations to Systematic Reasoning: A Connectionist Representation of Rule, Variables and Dynamic Bindings using Temporal Synchrony*. Behav. Brain Sci., Vol. 16:417-494.

1090. Sheer, D.E. (1989). *Sensory and Cognitive 40Hz Event-related Potentials Behavioral Correlates, Brain Function and Clinical Application.* In: E. Basar, T.H. Bullock, Eds., Springer Series in Brain Dynamics, Vol., 2:339-374. Springer.

1091. Shelhamer, M.; Robinson, D.A.; Tan, H.S. (1991). *Context-specific gain switching in the Human Vestibular Reflex.* In: B. Cohen, D.L. Tomko, F. Guedry, Eds., Annals of the New York Academy of Sciences, Vol. 656:889-891. New York Academy of Sciences, New York.

1092. Shibasaki, H.; Sadato, N.; Lyshkow, H.; Yonekura, Y.; Honda, M.; Nagamine, T.; Suwazono, S.; Magata, Y.; Ikeda, A.; Miyazaki, M. et al. (1993). *Both Primary Motor Cortex and Supplementary Motor Area play an important Role in Complex Finger Movements* Brain, Vol. 116:1387-1398.

1093. Siegel, D.J. (1999). *The Developing Mind: Toward a Neurobiology of Interpersonal Experience.* Book News, Inc., Portland.

1094. Siegle, G.J.; Steinhauer, S.R.; Thase, M.E.; Stenger, V.A.; Carter, C.S. (2002). *Can't Shake that Feeling: Event-Related fMRI Assessment of Sustained Amygdala Activity in Response to Emotional Information in Depressed Individuals.* Biological Psychiatry, Vol. 51:693-707.

1095. Siegler, R.S. (1981). *Developmental Sequences within and between Concepts*. Monographs of the Society for Research in Child Development, Vol. 46.

1096. Sillito, A.M.; Jones, H.E.; Gerstein, G.L.; West, D.C. (1994). *Feature-Linked Synchronization of Thalamic Relay Cell Firing induced by Feedback from the Visual Cortex.* Nature, Vol. 369:479-482.

1097. Simon, H.A. (1967). *Motivational and Emotional Controls of Cognition.* Psychological Review, Vol. 74:29-39.

1098. Singer, W.; et al. (1997). *Neuronal Assemblies: Necessity, Significance and Detectability.* Trends Cognitive Sciences, Vol. 1:252-261.

1099. Skinner B.F. (1938). *The Behaviour of Organisms: An Experimental Analysis.* Appleton-Century-Crofts, New York.

1100. Skinner, J.E., Yingling, C.D. (1977). *Central Gating Mechanisms that regulate Event-related Potentials and Behaviour*. In: J.E. Desmedt, Ed., Progress in Clinical Neurophysiology: Attention, Voluntary Contraction and Event-related Cerebral Potentials, Vol. 1:30-69. Karger, Basel.

1101. Sloman, A. (1987). *Motives, Mechanisms and Emotions.* Cognition and Emotion, Vol. 1:217-233.

1102. Smallman, H.S.; McKee, S.P. (1995). *A Contrast Ratio Constraint on Stereo Matching.* Proc. Royal Soc. Lond., B., Vol. 260:265-271.

1103. Snowden, R.J.; Treue, S.; Andersen, R.A. (1992). *The Response of Neurons in Areas V1 and MT of the Alert Rhesus Monkey to moving Random Dot Pattern.* Exp. Brain Res., Vol. 88:389-400.

1104. Solomon, K.O.; Medin, D.L.; Lynch, E. (1999). *Concepts Do More Than Categorize.* Trends Cognit. Sci., Vol. 3:99-104.

1105. Squire, L.R.; Cohen, N.J. (1984). *Human Memory and Amnesia.* In: G. Lynch, J.L. McGaugh, N.M. Weinberger, Eds., Neurobiology of Learning and Memory. Guilford, New York.

1106. Squire, L.R.; Kandel, E.R. (2000). *Memory: From Mind to Molecules.* W.H. Freeman and Co.

1107. Squire, L.R.; Kosslyn, S.M. (1998). Eds. *Findings and Current Opinion in Cognitive Neuroscience.* MIT Press, Cambridge MA.

1108. Srinivasan, R.; et al. (1999). *Increased Synchronization of Neuromagnetic Responses during Conscious Perception.* Journal of Neuroscience, Vol. 19:5435-5448.

1109. Staddon, J.E.R. (1983). *Adaptive Behavior and Learning*. Cambridge University Press.

1110. Stephan, K.M.; Fink, G.R.; Passingham, R.E.; Silbersweig, D.; Ceballos-Baumann, A.O.; Firth, C.D.; Frackowich, R.S.J. (1995). *Functional Anatomy of the Mental Representation of Upper Extremity Movements in Healthy Subjects.* J. Neurophysiol., Vol. 72:373-386.

1111. Steriade, M. (1968). *The Flash-evoked Afterdischarge*. Brain Res., Vol. 9:169-212.

1112. Steriade, M.; et al. (1996). *Synchronization of fast (30-4-Hz) spontaneous Cortical Rhythms during Brain Activation*. Journal of Neurosci., Vol. 16:392-417.

1113. Strother, S.C.; Anderson, J.R.; Schaper, K.A.; Sidtis, J.J.; Liow, J.S.; Woods, R.P.; Rottenberg, D.A. (1995). *Principal Component Analysis and the Scaled Subprofile Model compared to Intersubject Averaging and Statistical Parametric Mapping. I. 'Functional Connectivity' of the Human Motor System studied with Water PET*. J. Cereb. Blood Flow Metab., Vol. 15:738-753.

1114. Sutherland, R.J.; Rudy, J.W. (1989). *Configural Association Theory: The Role of the Hippocampal Formation in Learning, Memory and Amnesia.* Psychobiology, Vol. 17:129-144.

1115. Svrakic, D.M.; Whitehead, C.; Przybeck, T.R.; Cloninger, C.R. (1993). *Differential Diagnosis of Personality Disorders by the Seven Factor Model of Temperament and Character*. Arch. Gen. Psychiatry, Vol. 50:991-999.

1116. Takahashi, J.S.; Pinto, L.H.; Vitaterna, M.H. (1994). *Forward and Reverse Genetic Approaches to Behavior in the Mouse*. Science, Vol. 264:1724-1732.

1117. Tallal, P.; Jernigan, T.; Trauner, D. (1994). *Developmental bilateral Damage to the Head of the Caudate Nuclei: Implications for Speech-language Pathology*. J. Med. Speech Lang. Path., Vol. 2:23-28.

1118. Tallon-Baudry, C.; et al. (1996). *Stimulus Specificity of Phase-locked and Non-phase-locked 40Hz Visual Responses in Human*. J. Neurosci., Vol. 16:4240-4249.

1119. Tallon-Baudry, C.; et al. (1998). *Induced y-band Activity during the Delay of a Visual Short-term Memory Task in Humans*. Journal of Neuroscience, Vol. 18:4244-4254.

1120. Tanaka, K. (1993). *Neuronal Mechanisms of Object Recognition*. Science, Vol. 262:685-688.

1121. Tanaka, K.; Sugita, Y.; Moriya, M.; Saito, H-A. (1993). *Analysis of Object Motion in the Ventral Part of the Medial Superior Temporal Area of the Macaque Visual Cortex.* J. Neurophysiol., Vol. 69:128-142.

1122. Taylor, J.G. (1999). *Towards the Networks of the Brain: from Brain Imaging to Consciousness.* Neural Networks, Vol. 12:943-959.

1123. Taylor, J.G., Alavi, F.N. (1993). *Mathematical Analysis of a Competitive Network for Attention.* In: J.G. Taylor, Ed., Mathematical Approaches to Neural Networks, pp.341-382. Elsevier Science Publishers, Amsterdam.

1124. Taylor, J.G., Michalis, L. (1995). *The Functional Role of the Hippocampus in the Organization of Memory*. Proceedings of the International Neural Network Society Annual Meeting, July, 1995. International Neural Network Society Press, Washington, DC.

1125. Thompson, R.F. (1988). *The Neural Basis of Basic Associative Learning of Discrete Behavioral Responses.* Trends in Neurosciences, Vol. 11:152-155.

1126. Tomasello, M; Call, J. (1997). *Primate Cognition.* Oxford University Press.

1127. Tononi, G.; Edelman, G.M. (1998). *Consciousness and Complexity*. Science, Vol. 282:1846-1851.

1128. Treisman, A. (1996). *The Binding Problem*. Curr. Opin. Neurobiol., Vol. 6:171-178.

1129. Treisman, A. (1999). *Solutions to the Binding Problem: Progress through Controversy and Convergence*. Neuron, Vol. 24:105-110.

1130. Tsushima, T.; Takizawa, O.; Sasaki, M.; Shiraki, S.; Nishi, K.; Kohno, M.; Menyuk, P.; Best, C. (1994). *Discrimination of English /r-l/ and /w-y/ by Japanese infants at 6-12 Months: Language-specific Developmental Changes in Speech Perception Abilities*. Procced. Int. Conf. Spoken Lang. Process., Vol. 4:1695-1698.

1131. Tyszka, J.M.; Grafton, S.T.; Chew, W.; Woods, R.P.; Colletti, P.M. (1994). *Parceling of Mesial Frontal Motor Areas during Ideation and Movement using functional magnetic Resonance Imaging at 1.5 Tesla*. Ann. Neurol., Vol. 35:746-749.

1132. Ullman, S. (1984). *Early Processing of Visual Information.* In: M.S. Gazzaniga, Ed., Handbook of Cognitive Neuroscience. Plenum, New York.

1133. Ungerleider, L.G.; Courtney, S.M.; Haxby, J.V. (1998). *A Neural System for Human Visual Working Memory.* Proceedings of the National Academy of Sciences (USA), Vol. 95:883-890.

1134. Ungerleider, L.G.; Mishkin, M. (1982). *Two Cortical Visual Systems: Separation of Appearance and Location of Objects.* In: D.L. Ingle, M.A. Goodale, R.J.W. Mansfield, Eds., Analysis of Visual Behavior, Pp.549-586. MIT Press.

1135. Uylings, H.B.M.; Van Eden, C.G. (1990). *Qualitative and Quantitative Comparison of the Prefrontal Cortex in Rat and in Primates, including Humans.* Progress in Brain Research, Vol. 85:31-62.

1136. Van Gelderen, P.; Ramsey, N.F.; Liu, G.Y.; Duyn, J.H.; Frank, J.A.; Weinberger, D.R.; Moonen, C.T.W. (1995). *Three-dimensional functional magnetic Resonance Imaging of Human Brain on a clinical 1.5-T Scanner*. Proc. Natl. Acad. Sci. USA, Vol. 92:6906-6910.

1137. Vihman, M.M.; De Boysson-Bardies, B. (1994). *The Nature and Origins of Ambient Language Influence on Infant Vocal Production and Early Words*. Phonetica, Vol. 51:159-169.

1138. Viviani, P.; Laissard, G. (1996). *Motor Templates in Typing*. J. Exp. Psychol. (Hum. Percept. Perform.), Vol. 22:417-445.

1139. Von der Malsburg, C. (1973). *Self-organisation of Orientation-sensitive Columns in the Striate Cortex*. Kybernetik, Vol. 14:85-100.

1140. Von der Malsburg, C. (1981). *The Correlation Theory of Brain Function. (Internal Report 81-2).* In: E. Domany, et al., Eds., Models of Neural Networks, Vol. 2:95-119. Springer.

1141. Von der Malsburg, C. (1997). *The Coherence Definition of Consciousness.* In: M. Ito et al., Eds., Cognition, Computation and Consciousness, pp.193-204. Oxford University Press.

1142. Von Helmholtz, H.L.F. (1910-1925). *Treatise on Physiological Optics.* Dover Press.

1143. Waller, N.G.; Zavala, J.D. (1993). *Evaluating the Big Five*. Psychol. Inq., Vol. 4:131-135.

1144. Wanatabe, T.; Sasaki, Y.; Nielsen, M.; Takino, R.; Miyakawa, S. (1998). *Attention-Regulated Activity in Human Primary Visual Cortex.* J. Neurophysiol., Vol. 79:2218-2221.

1145. Warren, R. (1970). *Perceptual Restoration of Missing Speech Sounds*. Science, Vol. 167:392-393.

1146. Warrington, E.; Shallice, T. (1984). *Category Specific Semantic Impairments.* Brain, Vol. 107:829-854.

1147. Weinberger, N.M. (1956). *Retuning the Brain by Fear Conditioning.* In: M.S. Gazzaniga, E., The Cognitive Neurosciences, pp.1071-1090. MIT Press, Cambridge.

1148. Welch, R.B. (1986). *Adaptation of Space Perception.* In: K.R. Boff, L. Kaufman, J.P. Thomas, Eds., Handbook of Perception and Human Performance, Vol. 1:24. Wiley, New York.

1149. Welch, R.B.; Bridgeman, B.; Anand, S.; Browman, K.E. (1993). *Alternating Prism Exposure causes Dual Adaptation and Generalization to a Novel Displacement.* Perception and Psychophysics, Vol. 54(2):195-204.

1150. Wells, A. (2000). *Emotional Disorders and Metacognition: Innovative Cognitive Therapy.* New York: Wiley.

1151. Werker, J.F.; Polka, L. (1993). *The Ontogeny and Developmental Significance of Language-specific Phonetic Perception.* In: B. De Boysson-Bardies, S. De Schonen, P. Jusczyk, P. McNeilage, J. Morton, Eds.,Developmental Neurocognition: Speech and Face Processing in the First Year of Life, pp.275-288. Kluwer Academic Publishers, Dordrecht, Netherlands.

1152. Werker, J.F.; Tees, R.C. (1984). *Cross-language Speech Perception: Evidence for Perceptual Reorganization during the First Year of Life*. Infant Behav. Dev., Vol. 7:49-63.

1153. Wexler, M. (2001a). *Know thine own Action.* Trends in Cognitive Sciences, Vol. 5(7).

1154. Wexler, M. (2001b). *The Effect of Affect.* Trends in Cognitive Sciences, Vol. 5(7).

1155. Whalen, P. (1999). *Fear, Vigilance and Ambiguity: Initial Neuroimaging Studies of the Human Amygdala.* Curr. Dir. Psychol. Sci., Vol. 7:177-187.

1156. Wiener, S.I. (1993). *Spatial and Behavioral Correlates of Striatal Neurons in Rats performing a Self-initiated Navigation Task.* J. Neurosci., Vol. 13:3802-3817.

1157. Williams, C.L.; Barnett, A.M.; Meck, W.H. (1990). *Organizational Effects of Early Gonadal Secretions on Sexual Differentiation in Spatial Memory.* Behav. Neurosci., Vol. 104:84-97.

1158. Willshaw, D. (1981). *Holography, Associative Memory, and Inductive Generalization.* In: G. Hinton and J. Anderson, Eds., Parallel Models of Associative Memory, pp.103-122. (2nd Edition, 1989). Erlbaum, Hillsdale, NJ.

1159. Wilson, C.J. (1995). *The Contribution of Cortical Neurons to the Firing Patterns of Striatal Spiny Neurons.* In: J.C. Houk, J.L. Davis, D.G. Beiser, Eds., Models of Information Processing in the Basal Ganglia, pp.29-50. MIT Press,Cambridge, Massachusetts.

1160. Wolpert, D.M.; Kawato, M. (1998). *Multiple paired Forward and Inverse Models for Motor Control.* Neural Networks, Vol. 11:1317-1329. Elsevier Science Ltd.

1161. Wolpert, D.M.; Miall, R.C.; Kawato, M. (1998). *Internal Models in the Cerebellum.* Trends Cogn. Sci.

1162. Xu, F.; Carey, S. (1996). *Infants' Metaphysics: The Case of Numerical Identity.* Cognitive Psychology, Vol. 30:111-153.

1163. Young, A.W.; et al. (1995). *Face Processing Impairments after Amygdalotomy.* Brain, Vol. 118:15-24.

1164. Young, G.B.; Pigott, S.E. (1999). *Neurobiological Basis of Consciousness.* Arch. Neurol., Vol. 56:153-157.

1165. Zajonc, R. (1980). *Feeling and Thinking: Preferences Need No Inferences.* American Psychologist, Vol. 35:151-175.

1166. Zatorre, R.J.; Evans, A.C.; Meyer, E.; Gjedde, A. (1992). *Lateralization of Phonetic and Pitch Discrimination in Speech Processing.* Science, Vol. 256:846-849.