Cognition and Safety

An Integrated Approach to System Design and Assessment

Oliver Straeter

Ashgate. Aldershot. (ISBN 0754643255)

Detailed Table of Content

List of Figures	x
List of Tables	xiii
Abbreviations	xv
Preface	xvii
Acknowledgements	xix
Part I Concerns	1
1. The Need to Model Cognition in Safety	3
The Challenge of Cognition for Safe Design and Organisation of Systems Operational Levels 	3
Cognitive Aspects of System Safety	6
Cognitive Performance as a Common Cause of Accidents	10
A Proactive and Integrated View on Dealing with Cognitive Issues	12
• The Hindsight Nature of Human Factors	12
• Why is a More Coherent Picture of Cognition Needed?	14
• Questions for Developing a Proactive and Integrated Approach	21
2. The Genesis of Modelling Cognition in Safety	23
The Early Psychological Disputes from Behaviourism to Cognitivism	23
Behaviourism and Psychological Measurement	23
• The Discovery of the 'Mystical' Aspects of Active Human Behaviour	24
Cognitivism and Technomorphism	25
• The Gap between Issues and Models	28

	The Seduction and Constraint of Information Processing Stages	30
	The Inquisitory Logic of Modelling Information Processing Stages	31
	 Problems of Stage-based Approaches 	32
	Integration using Phases of Information Processing	35
	• The Mishandling of the Ladder-Model in Design and Safety	37
	• Attempts to Overcome the Limitations of the Ladder-Model	41
	• The Principle of Simplicity of Nature Applied to the Cognitive Levels	42
	The Importance of Context and Cognitive Control Modes for Understanding Human Errors	45
	Contextual Factors of the Working Environment	47
	Dynamic Situational Factors	49
	• Long-Term Effects of Inappropriate Context	55
	• The Combination and Interdependence of Contextual Factors	55
Pa	rt II Integration	59
3.	The Cognitive Processing Loop	61
	Characteristic of an Integrated Modelling of Information Processing for Safety	61
	• General Reflection of the Genesis	61
	Conclusion from the Genesis of Modelling Cognition	63
	The General Nature of Cognitive Modelling	68
	 Iterative Nature of any Scientific Loop of Progress 	69
	Requisite Variety	70
	Computational Effectiveness and Combinatory Explosion	71
	• Law of Uncertainty in Cognitive Modelling	72
	Basic Maxims for Cognition	72
	Cognition is Experience-based	73
	Cognition is Both Perception-Driven and Goal-Driven	73
	Cognition is a Process of Dynamic Binding	73
	Cognition needs Cognitive Dissonance	74
	Cognition means Reduction of Cognitive Dissonance	74
	 Cognition has Binary and Unspecific Mechanisms 	75

	Characteristics of the Cognitive Processing Loop	75
	• The Cognitive Mill	75
	Central Cognitive Acts	77
	• The Connectionism Nature of the Internal World	78
	• The Cognitive Loop of Processing Information	79
4. M	echanisms of Cognitive Performance and Error	81
	The Physiological Root of the Processing Loop	82
	• The Piece of Interest	82
	Neurological Issues	84
	Endocrine Issues	87
	• Relationship of Cognitive Aspects to Organic Regions in the Brain	88
	Behaviour as a Result of Cognitive Binding	89
	• Dynamic Binding and the Generic Architecture of Memory	89
	The Mathematical Calculus of Reasoning	97
	• Elements Determining Decision-Making	102
	Mental Utility and Comfort	112
	The Perspective of Cybernetics and Information Theory	117
	• The Architecture of the Central Comparator	117
	Reaction Time	126
	Memory Span	129
	• Learning	133
Part I	II Application	137
5. In	plications for Cognitive System Design	139
	Critical Dimensions of Human Information Processing	140
	Cognitive Control	141
	The System Ergonomic Framework for Cognitive Control Loops	142
	• A Framework for Describing Mental Load and Mental Complexity	147
	The Role of the Processing Loop in Communication	148
	Communication and Cognitive Control Modes	150
	Causes for Communication Failures	152
	Communication and Conflict	154

	Integrating Cognition into System-Organisation and -Management	159
	• Trust as a Consequence of the Cognitive Processing Loop	159
	Transition and Change-Management	160
	Risk Communication and Questioning Attitude	161
	Safety Management	163
	Integration of Cognition into Design and Operation	165
	• The Remote Access to Cognitive Performance in Design	165
	• The Cognitive Control Loop in Dynamic Situations	167
	Human Automation Management	169
	The Link of Retrospective Analysis and Prospective Assessment of Human Error	174
	• The CAHR Method	175
	• Semantic Coding of the Experiences Represented in Event Information	178
	• A Connectionism Approach for Data-Representation	179
	Detailed Analysis of Human Interventions	180
	• Operational Events as a Source to Represent the Experience Layer	181
6.	Assessment of Cognitive Performance in Safe Operations	185
	A Historical Overview of the Quantitative Assessment of Cognitive Performance in Safety Assessments	185
	• Human Reliability Assessment in the 1 st Generation	185
	• Methods in the Transition from 1 st to 2 nd Generation	188
	• Human Reliability Assessment in the 2 nd Generation	188
	• Résumé on the Representation of Cognitive Aspects in Safety Assessments	190
	Integrating Cognitive Performance and Safety Assessments	192
	Classifying Cognitive Performance and Error	192
	• A Descriptive Decision Model for Safety Assessments based on the Processing Loop	196
	Considerations on the Possibility to Quantify Cognitive Aspects	203
	Problems of Quantification	204
	Psychological Soundness of Quantitative Figures	205
	• The Law of Intransitive Statements	208
	Quantitative Assessment of Cognitive Processes	211
	• Approach of Using Events for Quantification	212
	A Calculus for Quantification	214

Assessing and Validating the Cognitive Processing Loop	218
• The Assessment of Cognitive Expectancy	218
• The Assessment of Mental Utility	221
• Experiences as an Approach to Assess Errors of Commission and Organisational Aspects	226
7. Integration of Cognitive Performance	231
The Classical Treatment of Cognitive Aspects in Safety Assessments	231
 Limitations of the Current Representation of Cognitive Aspects in Safety Assessments 	231
• An Integrated Approach of Assessing Cognitive Aspects in Design and Operation	234
The Importance of a Proactive Design and Assessment	237
 A Cross Industry View on Cognitive Science 	238
Overcome Hindsight on Human Cognition	239
8. Perspectives	241
Bibliography	
Author Index	
Keyword Index	

List of Figures

Figure 1.1	Interrelation of operational levels from design-level to working- level (adapted from Leveson, 2002)	5
Figure 1.2	Constraints on decision-making and induced mental workload	7
Figure 1.3	Cognitive properties as a common cause for degradation of	
8	system safety barriers	11
Figure 1.4	Project costs commitment in different product stages	13
Figure 1.5	Human Factor elements in different product stages	19
-		
Figure 2.1	The behaviourism paradigm	24
Figure 2.2	Wickens scheme of factors for human information processing; a	
	classical approach of integrating various cognitive findings	
	(according to Wickens, 1984)	31
Figure 2.3	The additive-factor logic or Sternberg paradigm	32
Figure 2.4	The ladder-model (according to Rasmussen, 1986, p. 7)	36
Figure 2.5	The GEMS-model (according to Reason, 1990)	43
Figure 2.6	Contextual factors of the working environment structured in the	
	Man-Machine System (MMS)	49
Figure 2.7	Dependencies of different causal factors in incidents (Sträter,	- 7
	1997/2000)	57
Figure 3.1	The iterative liaison of data and models	69
Figure 3.2	The cognitive mill (e.g. Neisser, 1976)	76
Figure 3.3	The cognitive processing loop – coherency between coupling	
	processes and experience-based knowledge	79
Figure 4.1	The piece of interest – The human brain	83
Figure 4.2	Representation of the example of Rosenfeld using bilateral	
	binding (from Dörner, 1997, p. 110)	89
Figure 4.3	Representation of one additional aspect of truth into the example $(D_{11}, D_{12}, D$	00
F' 44	of Rosenfeld (from Dorner, 1997, p. 110)	90
Figure 4.4	The principle of dynamic binding of information	93
Figure 4.5	binding of information	94
Figure 4.6	The experiences of the staff in the Tokai Mura accident	97
Figure 4.7	The calculus of information processing	99
Figure 4.8	Link of cognitive performance to behaviour	101
Figure 4.9	The role of settled experiences and generating of mind-sets	105
0		

Figure 4.10 Elements determining decision-making related to the processing loop 108 Figure 4.11 From tendencies to solve tasks to habits, attitudes and traits 117 Figure 4.12 Iterations of the cognitive processing loop 120 Figure 4.13 Processing of letters by the central comparator 123 Figure 4.14 The processing loop and simple reaction time 128 Figure 4.15 Activity diagram of four iterations of the cognitive processing loop 129 Figure 5.1 The human-human and human-system coupling 143 Figure 5.2 Impact of cognitive activities on communication quality 150 Figure 5.3 Profile of influences on procedural vs. verbal communication 153 Figure 5.4 Balance of conflict 156 Figure 5.5 Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system 161 Figure 5.7 Resolving mechanisms used during car driving 168 Figure 5.10 Event decomposition 177 Figure 5.11 Overview of the CAHR method 176 Figure 5.12 Event decomposition 177 Figure 5.13 Possible development of a situation into behavio	E: 110		
Figure 4.11 From tendencies to solve tasks to habits, attitudes and traits110Figure 4.12 Iterations of the cognitive processing loop120Figure 4.13 Processing of letters by the central comparator123Figure 4.14 The processing loop and simple reaction time128Figure 4.15 Activity diagram of four iterations of the cognitive processing loop129Figure 5.1 The human-human and human-system coupling143Figure 5.2 Impact of cognitive activities on communication quality150Figure 5.3 Profile of influences on procedural vs. verbal communication153Figure 5.4 Balance of conflict156Figure 5.5 Progressive and balanced development of trust as a result of the slugsishness and hysteresis of the cognitive system161Figure 5.7 Resolving mechanisms used during car driving168Figure 5.8 The general framework for skill set prediction in SHAPE170Figure 5.10 Event decomposition177Figure 5.11 Overview of the CAHR method176Figure 5.12 Event trace back into history from a defined error type to the underlying constraints181Figure 6.1 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.4 The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5 Hierarchy of data levels of measurement205Figure 6.7 The view on the distribution with non-resolvable intransitive statements209Figure 6.8 The view on the distribution with non-resolv	Figure 4.10	Elements determining decision-making related to the processing	100
Figure 4.11Fion tendencies to solve tasks to hanks, attudies and traits11/Figure 4.12Iterations of the cognitive processing loop120Figure 4.13Processing loop and simple reaction time128Figure 4.14The processing loop and simple reaction time128Figure 4.15Activity diagram of four iterations of the cognitive processing loop129Figure 4.16Number of decisions a human can perform per time130Figure 5.1The human-human and human-system coupling143Figure 5.2Impact of cognitive activities on communication quality150Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.10Event decomposition177Figure 5.11Overview of the CAHR method176Figure 5.12Event dacomposition180Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities184Figure 6.1Action tree and error probabilities186Figure 6.3From simple tasks to cognitive processing loop (related to the discussion in Part I of this book)193Figure 6.4The unfolded cognitive proc	Eiguro 4 11	100p From tandancias to solve tasks to babits, attitudes and traits	108
Figure 4.12 influtions of the cognitive processing foop120Figure 4.13 Processing of letters by the central comparator123Figure 4.14 The processing loop and simple reaction time128Figure 4.15 Activity diagram of four iterations of the cognitive processing loop129Figure 4.16 Number of decisions a human can perform per time130Figure 5.1 The human-human and human-system coupling143Figure 5.2 Impact of cognitive activities on communication quality150Figure 5.3 Profile of influences on procedural vs. verbal communication153Figure 5.4 Balance of conflict156Figure 5.5 Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.7 Resolving mechanisms used during car driving168Figure 5.8 The general framework for skill set prediction in SHAPE170Figure 5.10 Event decomposition177Figure 5.11 Overview of the Semantic processing of the event information180Figure 5.12 Event trace back into history from a defined error type to the underlying constraints181Figure 6.14 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop 	Figure 4.11	Iterations of the cognitive processing loop	117
Figure 4.15Froeessing of iterers by the central comparator125Figure 4.14The processing loop and simple reaction time128Figure 4.15Activity diagram of four iterations of the cognitive processing loop129Figure 4.16Number of decisions a human can perform per time130Figure 5.1The human-human and human-system coupling143Figure 5.2Impact of cognitive activities on communication quality150Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.10Event decomposition176Figure 5.11Overview of the CAHR method176Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.14Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop (related to the discussion in Part I of this book)202Figure 6.5Hierarchy of data levels of measurement statements205Figure 6.6The view on the distribution with non-resolvable intransitive statements201 </td <td>Figure 4.12</td> <td>Processing of letters by the control comparator</td> <td>120</td>	Figure 4.12	Processing of letters by the control comparator	120
Figure 4.14The processing loop and simple reaction time128Figure 4.15Activity diagram of four iterations of the cognitive processing loop129Figure 4.16Number of decisions a human can perform per time130Figure 5.1The human-human and human-system coupling143Figure 5.2Impact of cognitive activities on communication quality150Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict166Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.10Event decomposition177Figure 5.11Overview of the CAHR method176Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.5Hierarchy of data levels of measurement202Figure 6.5Hierarchy of data levels of measurement205Figure 6.4The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using re	Figure 4.15	The processing loop and simple reaction time.	123
Figure 4.15Activity diagram of rour iterations of the cognitive processing loop129Figure 4.16Number of decisions a human can perform per time130Figure 5.1The human-human and human-system coupling143Figure 5.2Impact of cognitive activities on communication quality150Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.10Event decomposition177Figure 5.11Overview of the CAHR method176Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The view on the distribution202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution with non-resolvable intransitive statements200Figure 6.7The view on the distribution w	Figure 4.14	Activity diagram of four iterations of the acquitive processing	128
Figure 1.16 Number of decisions a human can perform per time120Figure 4.16 Number of decisions a human can perform per time130Figure 5.1 The human-human and human-system coupling143Figure 5.2 Impact of cognitive activities on communication quality150Figure 5.3 Profile of influences on procedural vs. verbal communication153Figure 5.4 Balance of conflict156Figure 5.5 Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.7 Resolving mechanisms used during car driving168Figure 5.8 The general framework for skill set prediction in SHAPE170Figure 5.10 Event decomposition177Figure 5.11 Overview of the CAHR method167Figure 5.12 Event trace back into history from a defined error type to the underlying constraints181Figure 5.13 Possible development of a situation into behaviour182Figure 6.1 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3 Hierarchy of data levels of measurement202Figure 6.4 The view on the distribution208Figure 6.7 The view on the distribution with non-resolvable intransitive statements209Figure 6.8 The view on the distribution with non-resolvable intransitive attaments215Figure 6.9 Approach for using retrospective incident data for prospective design and assessment213Figure 6.1 Actser of cognitive errors in uncertainties of the intera	Figure 4.15	Activity diagram of four iterations of the cognitive processing	120
Figure 4.10 Number of decisions a number of perform performFigure 5.1Figure 5.1The human-human and human-system coupling143Figure 5.2Impact of cognitive activities on communication quality150Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.7Resolving mechanisms used during car driving180Figure 5.10Event decomposition177Figure 5.11Overview of the CAHR method176Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with non-resolvable intransitive statements210Figure 6.8The view on the distribution with non-resolvable intransitive design and assessment211Figure 6.9Approach for u	Figure 4 16	Number of decisions a human can perform per time	129
Figure 5.1The human-human and human-system coupling143Figure 5.2Impact of cognitive activities on communication quality150Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.7Resolving mechanisms used during car driving168Figure 5.7Resolving mechanisms used during car driving168Figure 5.7Resolving mechanisms used during car driving170Figure 5.7Event decomposition177Figure 5.10Event decomposition177Figure 5.11Overview of the Smantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities183Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.5Hierarchy of data levels of measurement202Figure 6.6The view on the distribution with resolvable intransitive statements209Figure 6.7The view on the distribution with non-resolvable intransitive design and assessment215Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215 <td>1 iguic 4.10</td> <td>runnoer of decisions a numan can perform per time</td> <td>150</td>	1 iguic 4.10	runnoer of decisions a numan can perform per time	150
Figure 5.2Impact of cognitive activities on communication quality150Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.7Resolving mechanisms used during car driving168Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.5Hierarchy of data levels of measurement202Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements209Figure 6.9Approach for using retrospective incident data for prospective design and assessment215Figure 6.10Assessment of cognitive errors in uncertainties of t	Figure 5.1	The human-human and human-system coupling	143
Figure 5.3Profile of influences on procedural vs. verbal communication153Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information181Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.7The view on the distribution208Figure 6.8The view on the distribution with non-resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive design and assessment213Figure 6.9Approach for using retrospective incident data	Figure 5.2	Impact of cognitive activities on communication quality	150
Figure 5.4Balance of conflict156Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 5.14Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.5Hierarchy of data levels of measurement202Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors	Figure 5.3	Profile of influences on procedural vs. verbal communication	153
Figure 5.5Progressive and balanced development of trust as a result of the sluggishness and hysteresis of the cognitive system161Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The view on the distribution202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive design and assessment215Figure 6.9Approach for using retrospective incident data for prospective design and assessment215Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.4	Balance of conflict	156
sluggishness and hysteresis of the cognitive system161Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.5Hierarchy of data levels of measurement202Figure 6.7The view on the distribution208Figure 6.8The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.5	Progressive and balanced development of trust as a result of the	
Figure 5.6Profile of influencing factors in relation to cognitive demand167Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 5.14Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.5Hierarchy of data levels of measurement202Figure 6.5Hierarchy of data levels of measurement205Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	U	sluggishness and hysteresis of the cognitive system	161
Figure 5.7Resolving mechanisms used during car driving168Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 5.14Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1Action tree and error probabilities186Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.6	Profile of influencing factors in relation to cognitive demand	167
Figure 5.8The general framework for skill set prediction in SHAPE170Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 5.14Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.5Hierarchy of data levels of measurement202Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements210Figure 6.8The view on the distribution with non-resolvable intransitive design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.7	Resolving mechanisms used during car driving	168
Figure 5.9Overview of the CAHR method176Figure 5.10Event decomposition177Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 5.14Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.5Hierarchy of data levels of measurement202Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive design and assessment210Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.8	The general framework for skill set prediction in SHAPE	170
Figure 5.10 Event decomposition177Figure 5.11 Overview of the semantic processing of the event information180Figure 5.12 Event trace back into history from a defined error type to the underlying constraints181Figure 5.13 Possible development of a situation into behaviour182Figure 5.14 Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3 From simple tasks to cognitively existing tasks199Figure 6.5 Hierarchy of data levels of measurement202Figure 6.6 The view on the distribution208Figure 6.7 The view on the distribution with resolvable intransitive statements209Figure 6.8 The view on the distribution with non-resolvable intransitive design and assessment210Figure 6.9 Approach for using retrospective incident data for prospective design and assessment215Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.9	Overview of the CAHR method	176
Figure 5.11Overview of the semantic processing of the event information180Figure 5.12Event trace back into history from a defined error type to the underlying constraints181Figure 5.13Possible development of a situation into behaviour182Figure 5.14Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with resolvable intransitive statements201Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.10	Event decomposition	177
Figure 5.12 Event trace back into history from a defined error type to the underlying constraints181Figure 5.13 Possible development of a situation into behaviour182Figure 5.14 Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3 From simple tasks to cognitively existing tasks199Figure 6.4 The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5 Hierarchy of data levels of measurement statements205Figure 6.7 The view on the distribution with resolvable intransitive statements209Figure 6.8 The view on the distribution with non-resolvable intransitive statements210Figure 6.9 Approach for using retrospective incident data for prospective design and assessment213Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.11	Overview of the semantic processing of the event information	180
underlying constraints181Figure 5.13 Possible development of a situation into behaviour182Figure 5.14 Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3 From simple tasks to cognitively existing tasks199Figure 6.4 The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5 Hierarchy of data levels of measurement205Figure 6.6 The view on the distribution208Figure 6.7 The view on the distribution with resolvable intransitive statements210Figure 6.8 The view on the distribution with non-resolvable intransitive statements211Figure 6.9 Approach for using retrospective incident data for prospective design and assessment213Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.12	Event trace back into history from a defined error type to the	
Figure 5.13 Possible development of a situation into behaviour182Figure 5.14 Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3 From simple tasks to cognitively existing tasks199Figure 6.4 The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5 Hierarchy of data levels of measurement205Figure 6.6 The view on the distribution208Figure 6.7 The view on the distribution with resolvable intransitive statements209Figure 6.8 The view on the distribution with non-resolvable intransitive statements210Figure 6.9 Approach for using retrospective incident data for prospective design and assessment213Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds215	-	underlying constraints	181
Figure 5.14 Necessity of a common language if retrospective analysis should be used for prediction183Figure 6.1 Action tree and error probabilities186Figure 6.2 Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3 From simple tasks to cognitively existing tasks199Figure 6.4 The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5 Hierarchy of data levels of measurement205Figure 6.6 The view on the distribution208Figure 6.7 The view on the distribution with resolvable intransitive statements209Figure 6.8 The view on the distribution with non-resolvable intransitive statements210Figure 6.9 Approach for using retrospective incident data for prospective design and assessment213Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.13	Possible development of a situation into behaviour	182
be used for prediction183Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive design and assessment210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 5.14	Necessity of a common language if retrospective analysis should	
Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215		be used for prediction	183
Figure 6.1Action tree and error probabilities186Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	-		
Figure 6.2Relation of dynamic situational conditions to the processing loop (related to the discussion in Part I of this book)193Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 6.1	Action tree and error probabilities	186
Figure 6.3From simple tasks to cognitively existing tasks193Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 6.2	Relation of dynamic situational conditions to the processing loop	102
Figure 6.3From simple tasks to cognitively existing tasks199Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements210Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	F: 6.0	(related to the discussion in Part I of this book)	193
Figure 6.4The unfolded cognitive processing loop from resolving mechanism to behaviour202Figure 6.5Hierarchy of data levels of measurement205Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements209Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 6.3	From simple tasks to cognitively existing tasks	199
Figure 6.5Hierarchy of data levels of measurement202Figure 6.6The view on the distribution208Figure 6.7The view on the distribution with resolvable intransitive statements209Figure 6.8The view on the distribution with non-resolvable intransitive statements209Figure 6.9Approach for using retrospective incident data for prospective design and assessment213Figure 6.10Assessment of cognitive errors in uncertainties of the internal and external worlds215	Figure 6.4	The unfolded cognitive processing loop from resolving	202
Figure 6.5 Filerarchy of data levels of measurement 205 Figure 6.6 The view on the distribution 208 Figure 6.7 The view on the distribution with resolvable intransitive statements 209 Figure 6.8 The view on the distribution with non-resolvable intransitive statements 210 Figure 6.9 Approach for using retrospective incident data for prospective design and assessment 213 Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 215	F irme C F	Microsoften of data locale of macrosoften and	202
Figure 6.6 The view on the distribution 208 Figure 6.7 The view on the distribution with resolvable intransitive statements 209 Figure 6.8 The view on the distribution with non-resolvable intransitive statements 210 Figure 6.9 Approach for using retrospective incident data for prospective design and assessment 213 Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 215	Figure 6.5	The size of data levels of measurement	205
Figure 6.7 The view on the distribution with resolvable intransitive statements 209 Figure 6.8 The view on the distribution with non-resolvable intransitive statements 210 Figure 6.9 Approach for using retrospective incident data for prospective design and assessment 213 Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 215	Figure 6.6	The view on the distribution with receivable internetities	208
Figure 6.8 The view on the distribution with non-resolvable intransitive statements 210 Figure 6.9 Approach for using retrospective incident data for prospective design and assessment 213 Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 215	Figure 0.7	the view on the distribution with resolvable intransitive	200
Figure 6.9 Approach for using retrospective incident data for prospective design and assessment 210 Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 213	Figura 6.8	The view on the distribution with non resolvable intransitive	209
Figure 6.9 Approach for using retrospective incident data for prospective design and assessment 213 Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 215	Figure 0.8	statements	210
Figure 6.9 Approach for using readspective meracht data for prospective design and assessment 213 Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 215	Figure 6.9	Approach for using retrospective incident data for prospective	210
Figure 6.10 Assessment of cognitive errors in uncertainties of the internal and external worlds 215	1 15010 0.7	design and assessment	213
and external worlds 215	Figure 6.10	Assessment of cognitive errors in uncertainties of the internal	
	0	and external worlds	215

Cognition and Safety

Figure 6.11 Figure 6.12	In-car display with secondary task Differences in reaction time responding to different symbols when performing the decision-response while driving and in the	219
	stationary condition	220
Figure 6.13	Frequency of failure occurrence for ignoring a critical alarm in a	
-	steer-by-wire car	224
Figure 6.14	Influencing factors and their interrelations	228
Figure 7.1	The safety assessment model from initiating event to safety	
	performance	232
Figure 7.2	Problems of the event sequence approach for including active	
-	human involvement (e.g. errors of commission)	233
Figure 7.3	The use of the cognitive processing loop in dynamic safety	
-	assessments	235

viii

List of Tables

Table 2.1	Broadening the model of Rasmussen by adding the goal-related aspects	42
Table 4.1	General allocation of cognitive characteristics and neural structures	88
Table 4.2	Logic reasoning as the relation between activation in the mirror and activation fed back to the central comparator	125
Table 5.1	Cognitive coupling of human and technical system	149
Table 5.2	Cognitive resolving mechanisms showed in events, most	
	overcome the situation	158
Table 5.3	Overview of the skill changes predicted and observed in the data- link experiment	172
T-1-1-52	Or and the shift shares and istal and shares dia the date	1/2
Table 5.5	link experiment (continued)	173
Table 5.4	Illustration of a sub-set of experiences as coded in the CAHR	
	method on the basis of a hypothetical example	179
Table 6.1	Cognitive error taxonomy based on the cognitive processing loop	197
Table 6.2	Parts of the cognitive control loop likely involved in cognitive	
	coupling	200
Table 6.3	Application of the CAHR method for predicting possible reactions of drivers to failures of the steer-by-wire systems in automobiles	