Contents

1	Inauguration	1
	Heiner Bubb	
1.1	Current Main Development Lines of the Automobile	2
1.2	Brief Historical Overview of Vehicle Development	
	from the User's Point of View	7
1.2.1	Development of the Driving Functions	7
1.2.2	Development of the Cockpit	11
1.3	The Importance of Ergonomics for Automotive Development	14
1.3.1	Brief Outline of the Development of Ergonomics	14
1.3.2	Micro Ergonomics and Macro Ergonomics	14
1.3.3	Subfield of Ergonomics	15
1.3.4	Fields of Application of Ergonomics	17
1.4	Hierarchy of the Driving Task	18
1.4.1	Primary Task	18
1.4.2	Secondary Tasks	20
1.4.3	Tertiary Tasks	21
1.5	Information Flows in Transport	21
	References	23
2	The Control Loop Paradigm of Ergonomics	25
	Heiner Bubb	
2.1	Driver-Vehicle Interaction	26
2.1.1	The Driver-Vehicle Control Circuit	26
2.1.2	Pursuit and Compensatory Task	28
2.1.3	Quality and Performance	29
2.1.4	Quality of Laterale Dynamics	29
2.1.5	Quality of Longitudinal Dynamics	30
2.2	Basic Concepts of System Technology	31
2.3	System Dynamics	35
2.3.1	Transition Functions and Frequency Response	35
2.3.2	Transition Function	36
2.3.3	Frequency Response	37
2.4	Quantities Controlled by the Driver	43
2.4.1	Laterale Dynamics	43
2.4.2	Longitudinal Dynamics	48
2.5	The Primary Driving Task from a Control Engineering Point of View	49
2.6	System Reliability	53
2.6.1	Safety, Risk, Border Risk and Protection	53
2.6.2	Reliability, Error and Safety	54
2.6.3	Human Error and Probability of Accident	56
2.6.4	Derivation of Measures from the Fault Tree Analyses	57
	References	60



3	The Human Being as a Driver	63
	Heiner Bubb, Mark Vollrath, Klaus Reinprecht, Erhard Mayer,	
	and Moritz Körber	
3.1	The Human Being as an Information Processing System	64
3.1.1	The System Model of the Driver	64
3.1.2	Anatomical-Functional Model	65
3.1.3	Functional-Neurophysiological Model	69
3.2	Elements of the Information Processing Human Being	77
3.2.1	Information Reception	77
3.2.2	Information Processing	101
3.2.3	Information Implementation	120
3.3	Information Processing when Driving a Car	123
3.3.1	The Feeling for the Time	123
3.3.2	Human Eye Behaviour when Driving a Passenger Car	124
3.3.3	Gaze Behaviour and Inner Models	141
3.3.4	Comfort and Discomfort	143
3.3.5	Stress and Strain	147
3.4	Driving Error	149
3.4.1	Human Reliability and Driving Errors	149
3.4.2	Causes of Human Error	151
	References	155
4	Anatomical and Anthropometric Characteristics	
	of the Driver	161
	Rainer E. Grünen, Fabian Günzkofer, and Heiner Bubb	
4.1	Anatomical Basics	162
4.1.1	The Musculoskeletal System	162
4.1.2	Muscular System	170
4.2	Anthropometry	176
4.2.1	Length and Circumference Dimensions	176
4.2.2	Weight	194
4.2.3	Forces	196
4.2.4	Mobility	205
7.2	References	213
	nerei erices	213
5	Human Models	219
	Heiner Bubb	
5.1	Cognitive Human Models	220
5.1.1	Control Engineering Models	220
5.1.2	The Benefits of Control Engineering Human Models	228
5.1.3	Cognitive Driver Models	229
5.2	Anthropometric Human Models	234
5.2.1	Drawing Templates	234
5.2.2	Digital Human Models	237
5.3	Summary Appreciation of the Benefits of Human Modelling	250
	References	251

	System Ergonomics of the Vehicle
	Heiner Bubb, Klaus Bengler, Jurek Breuninger, Christian Gold,
	and Magnus Helmbrecht
	General System Ergonomic Design Guidelines
1	Function
2	Feedback
.3	Compatibility
	Human – Machine – Interaction
1	Displays
2	Control Elements
	System Ergonomic Recommendations for the Respective
	Driving Task Levels
1	Primary Driving Task
2	Secondary Driving Task
3	Tertiary Tasks
•	Design of Driving Relevant Characteristics
1	Lateral Dynamics: The Steering Feel
2	Longitudinal Dynamics
3	X- by-Wire
,	References
	Neter et le constitution de la c
	Anthropometric Vehicle Design
	Heiner Bubb, Rainer E. Grünen, and Wolfram Remlinger
	Vehicle Packaging
1	Objective of the Anthropometric Package
2	Car Dimension Conception According to SAE
-	Fields of Anthropometric Ergonomics
	Sitting
!	Consideration of Different Anthropometries
2	Driver
3	Right-Hand Drive Problem
1	Co-Driver
	Vehicle Rear
5	View
ı	Direct View
2	Indirect Vision
<u>'</u>	View of Operating and Display Components
4	Reflections
	Operating and Display Components
1	Determination of Accessibility Areas According to SAE
2	Functional Gripping Spaces
3	Consideration of Special Operating Requirements
	Space Requirements
1	Static and Dynamic Space Requirements
2	Shelves
3	Room Feeling
	Entry and Exit
1	Door Concepts
2	Movement Strategies
3	Evaluation Methods

7.6.4	Access to the Second and Third Rows of Seats	449
7.7	Loading	449
7.7.1	Geometry	450
7.7.2	Operability	452
7.8	Consideration of Specific User Groups	453
7.8.1	Older Vehicle Users	453
7.8.2	Children	460
7.9	Craftsmanship	461
	References	465
8	Design of Condition Safety	469
	Heiner Bubb	
8.1	Lighting	470
8.1.1	Photometric Dimensions	470
8.1.2	Outdoor Lighting	471
8.1.3	Interior Lighting	472
8.2	Sound	475
8.2.1	Driving Noises	475
8.2.2	Small Noises	480
8.2.3	Useful Signals	482
8.3	Vibrations	483
8.3.1	Vibration Phenomena	483
8.3.2	Perception of Vibrations	483
8.3.3	Vibration Evaluation	485
8.3.4	Comfort and Driving Safety	490
8.3.5	Kinetosis	492
8.4	Climate	493
8.4.1	Climate, Performance and Comfort	493
8.4.2	Climatic Comfort	494
8.4.3	Environmental Conditions	499
8.4.4	Technical Requirements	501
8.5	Odour	513
	References	515
9	Driver Assistance	519
	Heiner Bubb and Klaus Bengler	
9.1	What Is Assistance?	520
9.2	Driver Assistance and Driving Task	522
9.2.1	Driver Assistance Systems Available Today for the Primary	
	Driving Task	523
9.2.2	Categorisation of Driver Assistance Systems for the Primary	
	Driving Task	548
9.2.3	Fatigue Warning	554
9.3	Contribution of Driver Assistance Systems to Driving Safety	558
9.4	Ergonomic Design	563
9.4.1	Operation and Display	563
9.4.2	Distinctness of the Modes of a Driver Assistance System	567
	References	570

10	Methods of Ergonomic Vehicle Development	575
	Heiner Bubb	
10.1	Ergonomics in the Vehicle Development Process	576
10.2	Virtual Reality	580
10.3	Simulation of Anthropometric Conditions	581
10.3.1	Seat Box	581
10.3.2	Variable Ergonomics Test Bench	582
10.3.3	Application of Virtual Reality	584
10.4	Simulation of Dynamic Driving and Traffic Aspects	589
10.4.1	Motivation for Driving Simulators and their Technical Challenge	589
10.4.2	Simulator Techniques	591
10.4.3	Relevance of Driving Simulators of Different Levels	596
10.4.4	Use of Augmented Reality in Real Vehicles	599
10.5	Experiments in a Real Vehicle	601
10.5.1	Trials on Closed off Terrain	601
10.5.2	Experiments on Public Roads	603
10.5.3	Customer Feedback	604
	References	605
11	Measurement Techniques	607
	Klaus Bengler, Heiner Bubb, Christian Lange,	
	Carmen Aringer-Walch, Nicole Trübswetter,	
	Antonia Conti-Kufner, and Markus Zimmermann	
11.1	Necessity of Experiments	608
11.1.1	Scientific Requirements for Experiments	608
11.1.2	Assessment of Usability	609
11.1.3	Design of Experiments	610
11.2	Objective Measurements	611
11.2.1	Recording of Individual Anthropometry	611
11.2.2	Recording of Posture and Body Movement	614
11.2.3	Capturing Contact Forces	617
11.2.4	Eye Movement	619
11.2.5	Performance Measurements	627
11.2.6	Physiological Parameters	632
11.3	Subjective Measurements	634
11.3.1	Psychophysics	634
11.3.2	Interview	639
11.3.3	Standardised Questionnaires	647
	References	648
		0.0
12	Statistical Methods	653
-	Mark Vollrath	
12.1	Basic Questions: Distribution Vs. Examination of Differences	654
12.2	Expression of Characteristics: Confidence Intervals	655
12.2.1	Methodology: Sampling	655
12.2.2	Statistics: Determination of Characteristic Value	656

XIV Contents

12.3	Differences Between Conditions: Significance Tests	659
2.3.1	Methodology: Experimental Designs	659
12.3.2	Statistics: Significance Tests	663
12.3.3	Statistics: Presentation of Results	669
12.4	External and Internal Validity	672
	References	673
13	Outlook	675
	Klaus Bengler and Heiner Bubb	
13.1	Electric Mobility	676
13.2	Automation	677
13.3	Mobility Behaviour	678
	References	678
	Supplementary Information	
	Index	683