

# Designing for Situation Awareness

An Approach to User-Centered Design

Second Edition

Mica R. Endsley and Debra G. Jones



**CRC Press**

Taylor & Francis Group

Boca Raton London New York

---

CRC Press is an imprint of the  
Taylor & Francis Group, an **informa** business

---

# Contents

Preface.....	xiii
Acknowledgments.....	xv
Authors.....	xvii

## ***PART I Understanding Situation Awareness in System Design***

<b>Chapter 1</b>	<b>User-Centered Design .....</b>	<b>3</b>
1.1	Who Is This Book for? .....	3
1.2	Why Do We Need User-Centered Design?.....	5
1.2.1	Technology-Centered Design .....	5
1.2.2	User-Centered Design .....	7
1.3	What Does User-Centered Design Mean?.....	7
1.3.1	What User-Centered Design Does Not Mean .....	7
1.4	Principles for User-Centered Design.....	9
1.4.1	Organize Technology around the User's Goals, Tasks, and Abilities .....	9
1.4.2	Technology Should Be Organized around the Way Users Process Information and Make Decisions .....	10
1.4.3	Technology Must Keep the User in Control and Aware of the State of the System .....	11
1.5	Situation Awareness: The Key to User-Centered Design.....	11
<b>Chapter 2</b>	<b>What Is Situation Awareness?.....</b>	<b>13</b>
2.1	SA Defined .....	13
2.1.1	Level 1 SA: Perception of Elements in the Environment.....	14
2.1.2	Level 2 SA: Comprehension of the Current Situation....	16
2.1.3	Level 3 SA: Projection of Future Status.....	18
2.2	Time as a Part of SA.....	19
2.3	Situation Awareness as a Product of the Process .....	19
2.4	Perception and Attention .....	20
2.5	Working Memory .....	20
2.6	Mental Models, Schema, and Scripts .....	21
2.7	Goals and SA.....	24
2.8	Expectations .....	27
2.9	Automaticity and SA .....	28
2.10	Summary .....	28

<b>Chapter 3</b>	<b>SA Demons: The Enemies of Situation Awareness.....</b>	<b>31</b>
3.1	Attentional Tunneling.....	31
3.2	Requisite Memory Trap.....	33
3.3	Workload, Anxiety, Fatigue, and Other Stressors.....	34
3.4	Data Overload.....	35
3.5	Misplaced Saliency.....	36
3.6	Complexity Creep.....	38
3.7	Errant Mental Models.....	39
3.8	Out-of-the-Loop Syndrome.....	40
3.9	Summary.....	41
<b>Chapter 4</b>	<b>Design Process.....</b>	<b>43</b>
4.1	Systems Development Life Cycle.....	43
4.1.1	Waterfall Model of Design.....	43
4.1.2	Concurrent Engineering Model.....	43
4.2	User Interface Design Process.....	45
4.2.1	Requirements Analysis.....	45
4.2.2	Technology Analysis.....	48
4.2.3	Design Conceptualization.....	48
4.2.3.1	Function Analysis/Function Allocation.....	49
4.2.3.2	User Interface Design.....	49
4.2.3.3	Design Concept Products.....	51
4.2.4	Prototype Development.....	52
4.2.4.1	Modeling.....	53
4.2.4.2	Rapid Prototyping.....	53
4.2.4.3	Simulation Testing.....	54
4.2.4.4	Field Tests.....	55
4.2.5	Test and Evaluation.....	56
4.2.5.1	Subjective Measures.....	56
4.2.5.2	Objective Measures of Performance.....	57
4.2.5.3	Workload Measures.....	57
4.2.5.4	Situation Awareness Measures.....	58
4.2.6	Final Design.....	59
4.3	Situation Awareness-Oriented Design.....	59

## ***PART II Creating Situation Awareness-Oriented Designs***

<b>Chapter 5</b>	<b>Determining SA Requirements.....</b>	<b>63</b>
5.1	Goal-Directed Task Analysis.....	63
5.2	Methodology Overview.....	64
5.3	Interviews.....	64

5.4	Determining the Preliminary Goal Structure .....	67
5.4.1	Goal Determination.....	68
5.4.1.1	Goals versus Tasks.....	68
5.4.1.2	Goals versus Information Requirements ....	69
5.4.1.3	Callouts.....	71
5.4.1.4	Summary .....	71
5.4.2	Decisions .....	72
5.4.3	SA Requirements.....	72
5.4.4	General .....	74
5.5	Future Interviews.....	74
5.6	Interview Issues .....	75
5.6.1	Maximizing Data Collection.....	75
5.6.2	Participant Personality Factors.....	75
5.6.3	Audio/Video Recording .....	76
5.7	Organizational Tips .....	77
5.8	GDTA Validation.....	77
<b>Chapter 6</b>	<b>Principles of Designing for SA .....</b>	<b>79</b>
6.1	From Theory to Design .....	79
6.2	Case Study: SA-Oriented Design .....	84
6.2.1	MCC SA Requirements Analysis.....	85
6.2.2	MCC System Evaluation .....	85
6.2.2.1	Lack of Integration of Information.....	96
6.2.2.2	Lack of Required Information .....	96
6.2.2.3	Poorly Presented or Lacking Information to Support Diagnosis .....	96
6.2.2.4	Major Functions Not Supported .....	97
6.2.2.5	Integration Time Consuming.....	97
6.2.2.6	Information Not Made Explicit .....	97
6.2.2.7	Needed Communications Sporadic .....	97
6.2.2.8	Information on Adjacent Sector Activities Not Provided.....	98
6.2.2.9	Global SA Poor.....	98
6.2.2.10	Data Overload.....	98
6.2.2.11	Poor User Interfaces .....	98
6.2.3	Situation Awareness-Oriented Interface Design .....	99
6.2.3.1	Hardware .....	100
6.2.3.2	Status Map .....	100
6.2.3.3	Status .....	102
6.2.3.4	Activity .....	103
6.2.3.5	History .....	106
6.2.3.6	Comms.....	107
6.2.3.7	Set-Up .....	107
6.2.3.8	Weather Map.....	109
6.2.4	Summary of Interface Design Case Study .....	110

<b>Chapter 7</b>	<b>Confidence and Uncertainty in SA and Decision Making</b> .....	113
7.1	Uncertainty .....	113
7.2	Types and Sources of Uncertainty.....	113
7.2.1	Level 1: Data Uncertainty .....	113
7.2.2	Level 2: Comprehension Uncertainty.....	116
7.2.3	Level 3: Projection Uncertainty .....	116
7.2.4	Decision Uncertainty.....	116
7.3	Role of Confidence in Linking SA and Decision Making .....	117
7.4	Management of Uncertainty.....	118
7.4.1	Search for More Information.....	119
7.4.2	Reliance on Defaults .....	119
7.4.3	Conflict Resolution .....	119
7.4.4	Thresholding .....	120
7.4.5	Bet-Hedging and Contingency Planning.....	120
7.4.6	Narrowing Options.....	120
7.5	Design Principles for Representing Uncertainty.....	121
<b>Chapter 8</b>	<b>Dealing with Complexity</b> .....	131
8.1	Simplified View of Complexity .....	131
8.1.1	System Complexity.....	131
8.1.2	Operational Complexity .....	133
8.1.3	Apparent Complexity .....	135
8.1.3.1	Cognitive Complexity .....	135
8.1.3.2	Display Complexity .....	139
8.1.3.3	Task Complexity .....	140
8.1.4	Role of the User's Mental Model.....	141
8.2	Design Principles for Taming Complexity .....	142
<b>Chapter 9</b>	<b>Alarms, Diagnosis, and SA</b> .....	147
9.1	An Alarming Practice .....	147
9.2	Processing Alarms in the Context of SA.....	148
9.2.1	Alarm Reliability.....	149
9.2.2	Confirmation .....	152
9.2.3	Expectancy .....	153
9.2.4	Disruptions and Diversions .....	155
9.2.5	Workload and Alarms .....	155
9.2.6	Alarm Formats and Compliance.....	157
9.2.7	Diagnosis of Alarms.....	158
9.2.8	Alarm Reduction Schemes .....	160
9.3	Principles for the Design of Alarm Systems .....	161

<b>Chapter 10</b>	<b>Automation and Situation Awareness .....</b>	<b>169</b>
10.1	Automation: A Help or a Hindrance? .....	169
10.2	Out-of-the-Loop Syndrome .....	171
10.2.1	Vigilance, Complacency, and Monitoring .....	173
10.2.2	Active versus Passive Processing .....	175
10.2.3	System Feedback Quality .....	176
10.3	Automation and Level of Understanding .....	177
10.4	Decision Support Dilemma .....	179
10.5	New Approaches to Automation .....	182
10.5.1	Adaptive Automation .....	182
10.5.2	Levels of Automation .....	184
10.6	Principles for Designing Automated Systems .....	186
<b>Chapter 11</b>	<b>Designing to Support SA for Multiple and Distributed Operators .....</b>	<b>193</b>
11.1	Team Operations .....	193
11.2	SA in Teams .....	195
11.3	What Is Shared SA? .....	196
11.4	Critical Factors Affecting SA in Teams .....	198
11.4.1	Shared SA Requirements .....	199
11.4.2	Shared SA Devices .....	202
11.4.3	Shared SA Mechanisms .....	204
11.4.4	Shared SA Processes .....	206
11.4.5	Interrelationship between Factors .....	208
11.5	SA in Distributed Teams .....	208
11.6	SA Breakdowns in Teams .....	210
11.7	Design Principles for Supporting Team Operations .....	213
<b>Chapter 12</b>	<b>Unmanned and Remotely Operated Vehicles .....</b>	<b>219</b>
12.1	Unmanned Vehicles for Many Uses .....	219
12.2	Classes of Unmanned Vehicle Control .....	219
12.3	Human Error in Unmanned Vehicle Operations .....	221
12.4	Situation Awareness Requirements for Unmanned Vehicle Operations .....	223
12.5	Challenges for SA in Remote Operations .....	223
12.5.1	Poor Sensory Data, Intermittent Data, and Time-Lags .....	226
12.5.2	Difficulties in Unmanned Vehicle Localization .....	226
12.5.3	Demanding Tasks in Complex Environments .....	226
12.5.4	Low-Level Data Overload and Interface Design .....	227
12.5.5	Multitasking in Unmanned Vehicle Operations .....	227
12.5.6	Lack of Support for Multi-Person Operations .....	228
12.5.7	Increased Autonomy for Unmanned Vehicle Operations .....	228

12.6	Factors for Effective Design of Unmanned Vehicle Tasks and Systems .....	229
12.6.1	Unmanned Vehicle Displays .....	229
12.6.2	Unmanned Vehicle Controls .....	230
12.6.3	Multiple Unmanned Vehicle Controls.....	231
12.6.4	Support for Team Coordination and Collaboration .....	231
12.7	Summary .....	233
<b>Chapter 13</b>	<b>SA Oriented Training.....</b>	<b>235</b>
13.1	Need for Training to Enhance SA .....	235
13.2	Challenges for Novices.....	235
13.3	Mental Models Form a Key Mechanism for Expertise .....	236
13.4	Schema of Prototypical Situations or Patterns .....	238
13.5	Critical Skills for SA .....	239
13.6	Examples of SA Deficits in Novices.....	239
13.7	Training Approaches for Improving Situation Awareness ....	244
13.7.1	Classroom and Exercise-Based Training Approaches.....	245
13.7.2	SA Trainer for General Aviation .....	246
13.7.3	Interactive SA Trainer .....	247
13.7.4	Virtual Environment Situation Awareness Review System .....	249
13.7.4.1	SA Behavioral Rating .....	249
13.7.4.2	SA Communications Rating .....	249
13.7.4.3	SA Probes .....	250
13.7.4.4	Use of VESARS in After Action Reviews .....	251
13.7.5	Situation Awareness Virtual Instructor.....	254
13.8	Summary .....	255

## ***PART III Completing the Design Cycle***

<b>Chapter 14</b>	<b>Evaluating Design Concepts for SA.....</b>	<b>259</b>
14.1	Indirect Measures of Situation Awareness .....	260
14.1.1	Process Measures .....	260
14.1.1.1	Verbal Protocols .....	260
14.1.1.2	Communication Analysis .....	261
14.1.1.3	Psychophysiological Metrics.....	262
14.1.2	Behavioral and Performance-Based Measures .....	263
14.1.2.1	Behavioral Measures .....	264
14.1.2.2	Performance Outcome Measures.....	265

14.2	Direct Measures of Situation Awareness.....	266
14.2.1	Subjective Measures.....	266
14.2.1.1	Situational Awareness Rating Technique.....	268
14.2.1.2	Situation Awareness–Subjective Workload Dominance Technique .....	269
14.2.1.3	Situational Awareness Rating Scale .....	269
14.2.2	Objective Measures .....	270
14.2.2.1	Situation Awareness Global Assessment Technique.....	270
14.2.2.2	Online Probes .....	276
14.3	Measuring Team SA.....	277
14.4	Case Study .....	279
14.4.1	Test Case and Testing Description .....	279
14.4.2	Implementation and Analysis of SA Measures .....	280
14.5	Summary .....	283
<b>Chapter 15</b>	<b>Applying SA-Oriented Design to Complex Systems .....</b>	<b>285</b>
15.1	Combating the Enemies of Situation Awareness.....	288
15.1.1	Attentional Narrowing .....	289
15.1.2	Requisite Memory Trap.....	290
15.1.3	Workload, Anxiety, Fatigue, and Other Stressors.....	290
15.1.4	Data Overload.....	291
15.1.5	Misplaced Salience.....	291
15.1.6	Complexity Creep.....	292
15.1.7	Errant Mental Models .....	293
15.1.8	Out-of-the-Loop Syndrome.....	293
15.2	SA-Oriented Design Synergy .....	294
15.3	System Evaluation .....	295
15.4	Future Directions.....	296
<b>Appendix A:</b>	<b>Goal-Directed Task Analysis for Commercial Airline Pilots.....</b>	<b>297</b>
<b>References</b>	.....	<b>339</b>
<b>Index</b>	.....	<b>365</b>