

Contents

List of Abbreviations	IX
1 Introduction	1
1.1 Virtual Realities as Multi-Purpose Technology	2
1.1.1 What is Virtual Reality?	2
1.1.2 Applications and Requirements	4
1.1.3 State-of-the-Art VR Technology and Current Limitations	8
1.2 Understanding Human Perception	17
1.2.1 What is Perception?	17
1.2.2 The Difficulty of Measuring Human Perception	18
1.2.3 Human Perception in the Context of Virtual Reality	19
1.3 The Role of Eye Height in the Real World and Virtual Reality	19
1.4 Organization of this Dissertation	20
1.4.1 Contributions of the Candidate	21
2 Perceiving Distance in Real and Virtual Environments	25
2.1 The Basics of Human Distance Perception	26
2.1.1 The Nature of the Information Specifying Depth	26
2.1.2 Sensory and Depth Cues for Perceiving Space	27
2.1.3 Measurement Methods and Performance	32
2.2 Distance Perception in Virtual Environments	36
2.2.1 The Underestimation of Distance	37
2.2.2 Technical Factors	38
2.2.3 The Availability of Depth Cues	44
2.2.4 Attempts to Counter Underestimation of Distance in IVEs	45
2.3 The Relation between Eye Height and Perceiving Space	50
2.3.1 Object Height and Affordances	50
2.3.2 Perceiving Distances using Eye Height	52
3 Investigating how Eye Height is Informed and Corresponding Hypotheses	55
3.1 Motivation	55
3.1.1 Perceptual Theory	56
3.1.2 Applied Problem Solving	58

3.2	Research Questions and Corresponding Hypotheses	60
3.2.1	What Sensory Information is used to determine Eye Height?	60
3.2.2	Is Eye Height for Perceiving Distances informed by changes in Posture? . .	60
3.2.3	Is eye height in VR informed differently from eye height in the real world? .	61
3.2.4	Can Virtual Eye Height manipulations be used to Reduce or even Counter Distance Underestimation?	61
4	Sensory Information for determining Eye Height for Egocentric Distance Perception in Different Postures	63
4.1	Introduction	63
4.2	Experiment 1: Manipulating Visual Eye Height in VR in a Standing Posture . .	65
4.2.1	Method	65
4.2.2	Results & Discussion	67
4.3	Experiment 2: Manipulating Visual Eye Height in VR in a Sitting Posture . . .	69
4.3.1	Method	70
4.3.2	Results & Discussion	71
4.4	Experiment 3: Manipulating Visual Eye Height in VR in an Uncommon Prone Posture	71
4.4.1	Method	73
4.4.2	Results & Discussion	74
4.5	Experiment 4: The Reliability of Visual Information for Determining Eye Height in VR	75
4.5.1	Method	76
4.5.2	Results & Discussion	77
4.5.3	Considering the Error	78
4.6	Determining Eye Height and Distances in the Real World	78
4.7	Experiment 5: The Role of Body-based Eye Height versus Internalized Knowledge of Eye Height in the Real World	79
4.7.1	Method	79
4.7.2	Results & Discussion	81
4.8	Experiment 6: Usage of Body-Based Eye Height with a Shifted Frame of Reference in the Real World	84
4.8.1	Method	84
4.8.2	Results & Discussion	85
4.9	Summary & Discussion	88
5	Eye Height Manipulations to Improve Distance Perception in Virtual Reality	91
5.1	Introduction	91
5.2	Experiment 7: The Influence of a Manipulated Eye Height on an Action-Based Measure	94
5.2.1	Method	94
5.2.2	Results & Discussion	96

5.3	Experiment 8: Manipulating Eye Height to Reduce Distance Underestimation	100
5.3.1	Method	102
5.3.2	Results & Discussion	102
5.4	Experiment 9: The Influence of the Retinal Size of the Unfamiliar Target Size	104
5.4.1	Method	104
5.4.2	Results & Discussion	104
5.5	Experiment 10: Manipulating Eye Height to Counter Distance Underestimation in a Rich-Cue Virtual Space	107
5.5.1	Method	107
5.5.2	Results & Discussion	107
5.6	Experiment 11: Manipulating Eye Height Factoring in Underestimation	111
5.6.1	Method	111
5.6.2	Results & Discussion	112
5.7	Summary & Discussion	116
6	General Discussion	119
6.1	Summary of the Empirical Results	119
6.2	The Importance of Body-Based Information in Visual Perception	122
6.3	Understanding Visual Perception to Increase the Utility of VR	123
6.4	Further Questions and Future Work	125
7	Implications of the Current Work	129
7.1	Novel Theoretical Implications	129
7.2	Novel Practical / Applied Implications	130
8	Summary	133
Bibliography		135