CONTENTS

1 INTRODUCTION 1
1.1 Outline of the thesis . . . 2
1.2 Virtual Reality . . . 3
1.3 Virtual Reality applications . . . 4
1.3.1 Entertainment . . . 4
1.3.2 Visualization, prototyping and planning . . . 5
1.3.3 Simulations, training and education . . . 6
1.3.4 Virtual Reality applications used for medical purposes and education . . . 7
1.4 Aim of this dissertation . . . 8
1.5 Contribution of the candidate . . . 9
1.5.1 Novelties of the dissertation . . . 9
1.5.2 Contributions to VR applications . . . 10
1.5.3 Contribution to body and space perception research in virtual reality . . . 10
1.5.4 Declaration of the contribution of the candidate . . . 11
2 STATE-OF-THE-ART AVATARS AND TECHNOLOGIES 13
2.1 State-of-the-art realistic avatars . . . 13
2.1.1 Creating stylized avatars . . . 13
2.1.2 Creating personalized avatars . . . 14
2.1.3 Static self-avatars . . . 14
2.1.4 Animating self-avatars in real-time . . . 15
2.2 Platforms for visualizing self-avatars and creating 3D interactive tools . . . 20
2.3 Tools for creating and animating computer graphics content . 20
2.4 Types of immersive display technologies used in VR systems 21
2.4.1 Head-mounted displays . . . 22
2.4.2 Large screen immersive displays . . . 23
2.5 Limitations . . . 25
3 RELATED RESEARCH 27
3.1 Body perception and embodiment . . . 27
3.1.1 Embodiment of artificial limbs in reality . . . 28
3.1.2 Embodiment in virtual reality applications . . . 28
3.1.3 Assessing perception of own body size using indirect measures . . . 29
3.1.4 Traditional methods for assessing perception of own body size . . . 30
3.1.5 Limitation of the traditional methods used for generating the visual stimuli used in body perception research 31
3.2 Perception of space and visual cues in immersive displays . . 31
3.2.1 Measuring egocentric distance perception in the real world and the VE . . . 32

3.2.2 Visual depth cues specific to LSIDs 33
3.2.3 Egocentric distance perception in LSIDs 34
4 MOTIVATION AND RESEARCH QUESTIONS 37
4.1 Motivation VR applications 37
4.2 How to provide realistic experience in VR? 38
4.3 Ownership over a considerably different self-avatar? 38
4.4 Precision of weight perception in VR and contribution of visual cues 39
5 OWNING AN OVERWEIGHT OR UNDERWEIGHT BODY 41
5.1 Materials and Methods 42
5.1.1 Ethics. 42
5.1.2 Technical Setup. 43
5.1.3 Visual Stimuli. 43
5.1.4 Response measures. 45
5.1.5 Participants. 46
5.1.6 The Experimental Design 46
5.1.7 Preparation for the experiment 48
5.1.8 Affordance estimation procedure 48
5.1.9 Body size estimation procedure 49
5.1.10 Visual-tactile stimulation procedure 49
5.2 Results 49
5.2.1 Analysis of the questionnaires 49
5.2.2 Analysis of the affordance and the body size estimations 50
5.2.3 Results - experienced body, physical body and virtual body 54
5.3 Discussion 57
5.3.1 Discussion about the subjective self-reports 57
5.3.2 Discussion about affordance and body size estimations 58
5.3.3 Distinction about the distinction between the physical, virtual and experienced body 59
5.4 Summary of the main findings 59
6 SPACE PERCEPTION IN LSIDS 61
6.1 Materials and methods 61
6.1.1 Technical setup 61
6.1.2 Visual stimuli 61
6.1.3 Experimental design 63
6.1.4 Experimental procedure 64
6.2 Egocentric distance perception in the real world 65
6.3 Egocentric distance perception in LSIDs 66
6.3.1 Semi-spherical large screen immersive display . . . 66
6.3.2 MPI cabin large screen immersive display 67
6.3.3 Flat large screen immersive display with stereoscopic projection and motion tracking 68
6.3.4 Overall Results 72
6.4 Discussion 75
6.5 Summary of the main findings 77

7 CAN I RECOGNIZE MY BODY'S WEIGHT? THE INFLUENCE OF SHAPE AND TEXTURE 79
7.1 Method . . . 79
7.1.1 Participants . . . 79
7.1.2 Generating virtual avatars based on 3d scan data . . 79
7.1.3 Preparing the avatars for the interactive 3D visualization platform . . . 83
7.1.4 Visual stimuli - virtual scene . . . 85
7.1.5 Experimental design . . . 85
7.1.6 Experimental procedure . . . 86
7.2 Results . . . 88
7.2.1 Sensitivity to own weight perception: difference for overweight vs. underweight . . . 88
7.2.2 The influence of shape (own vs. average) and texture (own photo-realistic vs. checkerboard pattern) on weight perception of avatars . . . 89
7.2.3 Method of adjustment for estimating current weight . 91
7.2.4 Considering possible confounds . . . 93
7.3 Discussion . . . 94
7.4 Summary of the main findings . . . 96
8 GENERAL DISCUSSION 97
8.1 Experience of ownership over a considerably different self-avatar in VR . . . 97
8.2 Designing LSID VR systems to provide a realistic experience 97
8.3 The contribution of visual cues and the precision of perception of own body weight portrayed by a personalized self-avatar 98
9 IMPLICATIONS FOR COMPUTER GRAPHICS AND VIRTUAL REALITY APPLICATIONS 99
9.1 Implications for designing LSID VR systems . . . 99
9.2 Implications for VR applications using self-avatars in HMDs 100
9.3 Implications for VR applications using personalized self-avatars 100
9.3.1 The contribution of visual cues and the properties of the body morphology to the perception of a personalized self-avatar . . . 100
9.3.2 Implications for clinical VR tools . . . 101
9.3.3 Clothing-fashion industry . . . 102
9.4 Implications for novel response measures . . . 102
10 CONCLUSION 105

BIBLIOGRAPHY 107