Gait Training after Stroke on a Self-Paced Treadmill with and without Virtual Environment Scenarios: A Proof-of-Principle Study

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ABSTRACT

Purpose: The purpose of this proof-of-principle study was to show that virtual reality (VR) technology could be coupled with a self-paced treadmill to further improve walking competency in individuals with chronic stroke. **Method:** A 62-year-old man with a chronic right hemispheric stroke participated in a treadmill walking programme involving first a control (CTL) protocol, then VR training. In CTL training, he walked without time constraints while viewing still pictures and reacting to treadmill movements similar to those that he would have experienced later in VR training. In VR training, he experienced treadmill movements programmed to simulate changes encountered in five virtual environments rear-projected onto a large screen. Training difficulty in nine sessions over 3 weeks was increased by varying the time constraints, terrain surface changes, and obstacles to avoid. Effects on walking competency were assessed using clinical measures (5 m walk test, 6 min walk test, Berg Balance Scale, Activities-specific Balance Confidence scale) and questionnaires (Assessment of Life Habits Scale and personal appraisal). **Results:** CTL and VR training resulted in a similar progression through the training sessions of total time walked on the treadmill. The VR training led to an additional increase in speed as measured by walking 5 metres as fast as possible and distance walked in 6 minutes, as well as improved balance self-efficacy and anticipatory locomotor adjustments. As reported by the participant, these improved outcomes transferred to real-life situations. **Conclusions:** Despite the limited potential for functional recovery from chronic stroke, an individual can achieve improvements in mobility and self-efficacy after participating in VR-coupled treadmill training, compared with treadmill training with the same intensity and surface perturbations but without VR immersion. A larger scale, randomized controlled trial is warranted to determine the efficacy of VR-coupled treadmill training for mobility intervention post-stroke.

Key Words: anticipatory locomotor control; self-efficacy; stroke; virtual reality; walking competency.

RÉSUMÉ

Objectif: la présente étude de validation visait à démontrer que la réalité virtuelle (RV) peut être jumelée à un tapis roulant autocontrôlé pour améliorer l'aptitude à marcher des personnes ayant un accident vasculaire cérébral (AVC) chronique. **Méthodologie :** un homme de 62 ans ayant un AVC chronique de l'hémisphère droit a participé à un programme de marche sur tapis roulant, d'abord au moyen d'un protocole de contrôle (CTL), puis d'un entraînement en RV. Pendant l'entraînement CTL, l'homme a marché sans contrainte de temps tout en regardant des images fixes et en réagissant aux mouvements du tapis roulant semblables à ceux repris par la suite en RV. Pendant l'entraînement en RV, il a ressenti les mouvements du tapis roulant programmés pour simuler les changements observés dans cinq environnements virtuels rétroprojetés sur grand écran. La difficulté de l'entraînement au cours de neuf séances réparties sur trois semaines a augmenté en variant les contraintes de temps, les changements de surface du terrain et les obstacles à éviter. Les chercheurs ont évalué les effets sur l'aptitude à marcher à l'aide de mesures cliniques (tests de marche de cinq mètres et de six minutes, échelle d'évaluation de l'équilibre de Berg, échelle de confiance en l'équilibre pendant des activités) et de questionnaires (échelle d'évaluation des habitudes de vie et évaluation personnelle). **Résultats :** l'entraînement CTL et celui en RV ont suscité une progression similaire de la durée totale de marche sur le tapis roulant pendant les séances d'entraînement. L'entraînement en RV a favorisé une amélioration supplémentaire de la marche rapide sur cinq mètres et de la distance parcourue en six minutes, de même qu'une meilleure auto-efficacité de l'équilibre et de meilleurs ajustements locomoteurs anticipés. Comme

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l'a indiqué le participant, cette amélioration des résultats se transposait dans la vie quotidienne. **Conclusions :** malgré le potentiel limité de récupération fonctionnelle en cas d'AVC chronique, une personne peut améliorer sa mobilité et son auto-efficacité après avoir participé à un entraînement sur tapis roulant jumelé à la RV, par rapport à un entraînement sur tapis roulant de la même intensité et selon les mêmes perturbations de la surface du sol, mais sans l'immersion de la RV. Un essai aléatoire et contrôlé à plus vaste échelle s'impose pour déterminer l'efficacité de l'entraînement sur tapis roulant jumelé à la RV dans le cadre d'une intervention de mobilité après un AVC.

Rehabilitation interventions using virtual reality (VR) consist of a range of computer technologies that can be used to artificially generate sensory information in the form of a virtual environment (VE) that is interactive and perceived as being similar to the real world.¹⁻³ Because it is not always feasible to physically replicate realistic community scenarios in a clinic or to safely train patients in the community, VR technology gives therapists a unique opportunity to expose patients to, and train them in, these scenarios in a risk-free and graded manner while providing intensive training and multi-sensory feedback^{1,4}

Jaffe and colleagues⁵ reported that persons with chronic stroke who had trained by stepping over virtual objects projected in a head-mounted display while walking on a motorized treadmill showed more improvements in fast walking and obstacle clearance than those who practised walking over real foam objects on a walkway. In another study that compared treadmill training alone with treadmill training while engaging in VR scenes,⁶ the VR group improved significantly more than the control group in walking speed and community walking time after training.

A recent scoping review⁷ has documented that 10 of 14 studies using gait speed as the main outcome reported significantly greater increases after VR-based intervention compared with other interventions. Other studies found significant improvements in other spatiotemporal gait parameters such as cadence,⁸ step length,⁸⁻¹⁰ step time,⁸ stride length,⁹ and gait symmetry,¹⁰ as well as larger lower limb joint excursion and ankle plantarflexion movement and power, for VR-based intervention^{11,12} over other interventions. A more recent systematic review¹³ focused on commonly assessed, clinical mobility outcome measures to examine the effectiveness of VR training in the population with subacute stroke. The meta-analyses conducted on gait speed, Berg Balance Scale scores, and timed up-and-go measures all favoured VR training when time dose was matched between balance and gait training with and without VR.

To our knowledge, however, other than training the locomotor adjustments that accompany the planning required for stepping over an obstacle,⁵ no studies have specifically targeted, simultaneously, the motor and cognitive demands of walking in a rich and changing environment in people with chronic stroke, especially individuals who need to improve their walking competency to meet the demands of community ambulation. As a result, our group has developed a VR-coupled treadmill system^{2,3,14,15} to enable training both the physical

and the cognitive components of gait, such as planning, decision making, and self-efficacy, in persons with chronic stroke.^{16,17} We undertook this study to show that VR could be applied to gait training and to estimate any VR-specific changes by comparing the mobility-related outcomes for one individual with chronic stroke who followed the locomotor VR-based training programme after completing a CTL training programme with the same intensity and treadmill perturbations. The results of this study have previously been presented at a conference.¹⁸

METHODS

Subject and design

A 62-year-old man entered the study 32 months after the onset of a right hemispheric stroke of thromboembolic origin. He walked with an ankle-foot orthosis on the left leg and used a cane. A retired manager of a large supermarket, he lived with his wife in his own home and participated in its upkeep. He understood directions well and could communicate verbally without difficulty. He first carried out a 3-week CTL protocol of treadmill training (walking while looking at still pictures). Twenty-six days after the follow-up evaluation of the CTL protocol—that is, with a washout period of more than 6 weeks—he began the VR training. Such a protocol, although limited by the sequential CTL training followed by the VR training, allowed us to estimate the effects that were specific to the VR training as a proof of concept to precede a larger scale, randomized controlled trial. The subject gave informed, written consent, and the ethics committee of our rehabilitation research centres approved the protocol.

Experimental procedures: the virtual reality-based locomotor training system

VR-based locomotor training is provided by means of a walking simulator that is coupled with VEs that are rear-projected onto a large screen. Details of this walking simulator and the first three VEs have been reported in earlier research.^{2,3,14,15} The subject, wearing a safety harness and stereo glasses, walked while using a sliding handrail (to simulate the use of a cane) on a self-paced, motorized treadmill mounted on a motion platform with six degrees of freedom and engaged in the VE scenarios. A dedicated microcontroller with a proportional-integral-derivative algorithm, based on the subject's position and obtained from a potentiometer tethered to his waist, enabled real-time matching of the subject's walking speed with the speed of the moving VE scene. VEs were

Figure 1 The first three levels of the VE: (a) screenshots of outdoor and indoor VEs used for the first three levels of training and (b) VR training progression in the corridor walking VE; red arrows (level 2) indicate terrain changes, and red circles (level 3) indicate moving obstacles. VE = virtual environment; VR = virtual reality.

created using Softimage XSI, version 2015 (Autodesk, San Rafael, CA) and controlled using the Computer Assisted Rehabilitation Environment (CAREN) system (Motek BV, Amsterdam).

Thus, the scene progression and the motions of the platform, which mimicked the terrain changes encountered in the VEs, were synchronized with the instantaneous treadmill speed and distance covered. Paradigms available in CAREN allowed us to vary the animation conditions (platform movements, timing, obstacle trajectories, and speeds), create ambient sounds, and detect collisions between the subject and obstacles. The results were displayed as short, positive or negative feedback animations, and a bar graph showed the subject's average walking speed, compared with his natural speed, for each trial.

The first three VEs (street crossing, corridor walking, and park stroll) incorporated parameters and features that we could manipulate to increase the difficulty of the walking task (level 1 = time constraint set; level 2 = terrain changes added; level 3 = moving obstacles added).

The distance walked in each VE was set to 40 metres; this corresponded to the street-crossing scene, thereby replicating a real environment. Thus, in level 1 training, the subject walked a distance of 40 metres within a set time. In level 2 training, we added surface perturbations to the various combinations of pitch and roll planes, and in level 3 training, we added moving obstacles (Figure 1). Two additional VEs (train station and beach walk) that used longer walking distances (90 m and 100 m, respectively) were included as an advanced level 4 progression (not shown) because they integrated all of the previous levels with increasing complexity.^{16–18}

Training procedures

The subject attended nine training sessions over a 3-week period for each programme. The set-up and preparation for each session in both programmes were similar and included a 3-minute treadmill habituation period (first with lights on and then with lights off) and continuous monitoring of heart rate and blood pressure. All training sessions were provided by the same therapist, who stood on the moving platform beside the subject.

Figure 2 Pictorial representation of the subject's progression through the training using characteristics of the virtual environment scenarios. S = session.

Control training protocol

The subject walked at his preferred walking speed while looking at still pictures of scenes (not related to walking), persons, or animals projected onto the screen for 8 seconds each. As he walked, he experienced random surface perturbations in the pitch and roll planes similar to those that he would later experience in VR training. He learned to react to these unexpected perturbations and to continue walking.

Virtual reality training protocol

The subject trained his walking skills with five VEs (Figure 2) that allowed for four levels of complexity. The choice of VE, the levels of difficulty, and the progression in the VEs were determined by a member of the team (FM) on the basis of clinical objectives for improving the subject's walking competency. For example, in session 1, he walked while engaging in three VEs at level 1. In session 4, he trained with the same three VEs, but with terrain changes (level 2) and moving obstacles (level 3). He began a level 4 scenario in session 5.

Three levels of difficulty were adjusted for the street crossing, corridor walking, and park stroll scenarios, in which the subject walked 40 metres. In level 1, he was given a set time to complete the trial without encountering changes in terrain or obstacles. The time given to complete the trial was initially based on approximately 75% of the subject's over-ground walking speed and was adjusted with his progression.

In level 2, terrain changes were added along with the time constraint. The subject experienced these changes

as forward-backward inclines, medio-lateral tilts, vertical displacements in the walking surface, or a combination of these movements. To help refine the progression of difficulty, the amplitude of the surface changes could be modulated from 25% to 100% of the amplitudes negotiated comfortably by healthy, well-habituated persons.

In level 3, the subject was required to make appropriate anticipatory locomotor adjustments to avoid collisions while also adapting to changes in terrain and facing the time constraint. Train station and beach walk were level 4 integrator scenarios, in which the subject walked 90 metres and 100 metres, respectively, and encountered a combination of time constraints, terrain changes, and moving obstacles.

Assessment procedures

Clinical measures

For each training protocol, evaluations were made before training (pre-training), after 3 weeks of training (post-training), and at 3-week follow-up (follow-up) by a research physiotherapist trained in applying these tests. The following measures were used to assess mobility and balance: the 5-metre walk test at comfortable and fast speeds,¹⁹ the 6-minute walk test,^{20–24} the Berg Balance Scale,^{25–28} and the Canadian French version (ABC-CF)²⁹ of the Activities-specific Balance Confidence scale.^{30–33}

Questionnaires

The Assessment of Life Habits Scale (Life-H), an instrument based on the Disability Creation Process model^{34,35} and validated to evaluate many aspects of the social

Figure 3 Graphical representation of walking time and speed during training: (a) time dedicated to habituation (CTL-H, VR-H) and gait training (CTL-W, VR-W) in each session and (b) minimum (CTLmin, VRmin) and maximum (CTLmax, VRmax) walking speeds during each session. CTL = control; VR = virtual reality.

participation of people with disabilities, was used to determine the impact of training on community integration. The analysis targeted 20 mobility-related life habits relevant to walking competency from the three dimensions of the test: Housing, Mobility, and Community Living. The Life-H questionnaire was administered by a specialist in this measure.

At the end of the study, the subject was interviewed by one of the investigators (FM) using a personal appraisal questionnaire. He responded to three questions designed to obtain his opinion on the CTL and VR training programmes and the effect of the training on his daily life.

RESULTS

Walking duration and speed during the training sessions

As illustrated in Figure 3a, for both the CTL and the VR training programmes, the time walked in the warm-up habituation period (white symbols) and during training in each session (dark symbols) was similar. In both training programmes, walking duration increased with successive sessions, and total training time for the CTL training and VR training amounted to 125.8 and 127.2 minutes, respectively. Figure 3b shows that, during CTL training (white and dark squares), when the subject

Table 1 Clinical Outcome Measures at Different Time Points

Measure	CTL training			VR training		
	Pre	Post	Follow-up	Pre	Post	Follow-up
5 m speed, m/s						
Comfortable	0.74	0.81	0.90	0.84	0.85	0.84
Fast	0.94	1.04	1.04	1.04	1.11	0.95
6MWT, m	304	325	307	326	362	334
Berg Balance Scale, max. 56	48	49	50	50	50	50
ABC-CF scale, max. 100	97	88	89	89	99	98
Life-H Housing*						
1. Sweeping and vacuuming inside your home	2	4	2	2	2	4
2. Making a bed	6	6	8	8	6	8
3. Emptying waste baskets and taking out the garbage	6	6	6	6	6	8
4. Entering and exiting your home	6	8	8	8	8	8
5. Moving from one room to another in your home	6	8	8	8	8	8
6. Moving around in your bathroom	6	8	8	8	8	8
7. Moving from one floor to another in your home	6	8	8	8	8	8
8. Getting from the street to the entrance of your home	6	6	6	6	6	8
9. Moving around the grounds of your home during the summer	6	8	6	6	8	8
Life-H Mobility*						
10. Getting around on the sidewalk	6	6	6	6	6	8
11. Getting around on the street	6	6	6	6	6	8
12. Crossing an intersection with a traffic light	6	6	6	6	6	8
13. Crossing an intersection without a traffic light	6	8	6	6	6	8
14. Getting around on uneven surfaces (grass, etc.)	6	6	6	6	6	8
15. Walking as a means of transportation	6	8	6	6	6	8
Life-H Community Life*						
16. Going to, entering, and moving around service establishments in your neighbourhood	6	8	8	8	6	8
17. Going to, entering, and moving around in local businesses	2	8	8	8	6	8

Note: Scores that improved by 2 points from pre-training to follow-up are italicized for CTL training and bolded for VR training.

*2 = accomplished with difficulty and required an assistive device (or adaptations) and human assistance; 4 = performed without difficulty but with an assistive device (or adaptation) and human assistance; 6 = performed with difficulty and required an assistive device (or adaptation); 8 = performed without difficulty with an assistive device (or adaptation).

CTL = control; VR = virtual reality; pre = pre-training; post = after 3 wk training; follow-up = at 3 wk follow-up; 6MWT = 6-minute walk test;

ABC-CF = Activities-Specific Balance Confidence scale, Canadian French version; Life-H = Assessment of Life Habits Scale.

walked at his preferred speed, the minimum and maximum speeds he attained changed very little. In contrast, during VR training (white and dark diamonds), the subject increased his maximum gait speeds from session to session, likely attesting to his continued interest and the challenges offered by the VEs.

After CTL training, comfortable and fast walking speeds increased by 0.7 metre/second (12%) and 1.0 metre/second (11%), respectively (Table 1). A 21-metre increase in the distance walked in 6 minutes (6.9%) was also observed. After VR training, additional increases in speed during fast walking (0.7 m/s, or 6.7%) and in the distance walked in 6 minutes (36 m, or 11%) were noted, and the comfortable walking speed remained unchanged. No positive effect on dynamic balance could be detected given the initial near-perfect score (therefore, showing a ceiling effect). However, the subject's perception of and confidence in his balance, as measured by the ABC-CF scale, changed over time. The very high initial score (97/100) decreased by 9 points in the post-CTL evaluation (88/100) and remained stable up to the start of VR training.

However, his confidence was regained with VR training (99/100) and at follow-up (98/100).

Initial scores for the 17 Life-H items (Housing, Mobility, and Community Life) that were 8 or more are presented in Table 1. Although a change in score of 0.5 points has been shown to be clinically significant in persons with stroke,³⁶ we took a conservative approach and considered changes of 2 or more at follow-up to be significant. The significant changes that occurred after the CTL training were related mostly to mobility in the home (items 1–7, 16, and 17, in italic), and those that occurred after the VR training were related to mobility outside the home and activities such as crossing a street (items 8–15, in bold).

The subject's responses to the questions about his appraisal of the two types of training are translated from French and presented in the Appendix. His responses underscore his improved confidence in his walking capacity, especially outdoors; his improved planning and decision-making ability; and his expression of newfound self-efficacy.

DISCUSSION

In this proof-of-principle study, we examined the effects of a VR-based locomotor training programme that challenged both the physical and the cognitive dimensions of gait on different outcomes characterizing mobility, balance, and community integration. Our findings indicated that VR training not only led to improvements in some physical aspects of walking but also specifically improved balance self-efficacy and promoted the development of confidence in walking capacity, locomotor planning abilities, and anticipatory locomotor adjustments.³⁷ Evidence of motor planning and anticipatory adjustments stemmed from biomechanical gait measures (not reported here) and from the subject's appraisal of the VR training.

The subject reported that the perturbations he experienced while walking on the treadmill corresponded to what he saw in the VEs. For example, when an avatar was about to cross in front of him in the train station scenario, he learned to modify his speed to avoid it. He also saw upcoming terrain changes, such as in the corridor walking scenario, and maintained upright balance to counter the pitch-and-roll motions of the treadmill, which mimicked those terrain changes (see Figure 1b). Moreover, a transfer to real-life situations occurred, as the subject reported in the personal appraisal questionnaire (see the Appendix). Indeed, an important component of gait training, one that can be uniquely and safely applied using VR, is training a subject to make anticipatory locomotor adjustments, such as adapting posture and instantaneous speed in anticipation of surface perturbations and upcoming obstacles. Although postural reactions can be elicited with a self-paced treadmill capable of random surface perturbations, as achieved with CTL training, anticipatory adjustments can be trained only when upcoming perturbations are visually detected, as in the VEs we used. Thus, VR gait training can target both avoiding obstacles³⁷ and adapting to changing terrain, both of which are considered essential to independent community ambulation.³⁸

Although the 3-week CTL walking programme did not focus on increasing walking speed or endurance as such, the training had some effects on physical conditioning. In addition, the VR training yielded further improvement in fast walking speed; this could be related to the walking "sprints" required in the VEs when, for instance, the subject increased his speed to avoid obstacles, catch a train, or cross a street. Speed modulation is especially relevant to community ambulation. It is also noteworthy that the added complexity of the VR did not delay the progression of the training or require more habituation because of increased cognitive processing because the subject achieved the same amount of walking practice through all nine sessions of the VR training as in the

CTL training (see Figure 3). Finally, the increase in walking distance that the subject achieved after the VR training could be related to the training that occurred during the nine additional sessions of VR training and, likely, to an increase in walking activities outside the training sessions, given the subject's augmented confidence in his walking ability (see Appendix).

The near maximal ABC-CF score before CTL training (97/100) indicates that the subject was confident in most balance activities, but it decreased by 9 points after CTL training and remained stable in the follow-up evaluation. Such a decrease can be interpreted as a response shift,³⁹ which is not uncommon for self-reported measures, when subjects realize that a task is more difficult to perform during daily activities than initially perceived. The stability of the scores in the three tests after the first pre-training score suggests that the subject learned to more correctly grade his confidence. VR training led to a 10-point improvement over this new baseline, twice the 5-point change needed to be minimally clinically significant in persons after stroke.³³

Changes in accomplishment scores for the life habits that required a combination of mobility and use of the hands and executive functioning related to locomotion revealed that the VR training led to improvements beyond those attained after the CTL training. For example, the subject further improved his score for making a bed or carrying out the garbage as well as for habits related to mobility in the community, such as crossing a street. These findings suggest that the VR training produced added benefits for life habits requiring motor planning, the combination of motor tasks and decision making.

The subject's responses to the questions that were put to him converge with our findings from the ABC-CF scale and the Life-H by indicating that he had transferred the skills he had practised during the VR training to real-life situations. He emphasized the importance of the self-confidence that he had gained from the VR training and the sense of self-efficacy and empowerment that he felt when faced with novel situations.

CONCLUSIONS AND CLINICAL IMPLICATIONS

This subject with chronic stroke found that the VR training was motivating and resulted in improvements in both the physical and the cognitive aspects of his walking ability in real life. Not only was he able to walk faster and farther, but he was also able to adapt his walking speed and function better in community-related mobility and locomotion-related life habits. He also reported that he had learned to better plan his locomotor strategies and make better decisions. Overall, he had more self-confidence and a sense of improved self-efficacy and empowerment. Collectively, these results show that gait training using VR has the potential to improve functional mobility after stroke. Although the

improvements can be attributed to both VR and treadmill gait training, it seems that VR leads to additional functional gains in speed and endurance as well as in self-efficacy. Thus, VR training can be used as a tool to enhance community ambulation in persons with chronic stroke. Nevertheless, a larger scale, randomized controlled trial is warranted to determine the efficacy of VR-coupled treadmill training for mobility intervention after stroke.

This study does have its limitations. First, the results need to be seen in context: The participant was a person with chronic stroke who was highly motivated, capable of participating in the training regimen, and able to express himself. Further studies are needed to characterize the ideal amount of VR intervention needed to yield optimal improvements and to determine how patients with different levels of motor and cognitive deficits respond to the intervention. Second, given the cost and complexity of the VR training system and the human resources needed to deliver such an intervention, further work is needed to develop less costly, streamlined, and safe systems that are conducive to clinical applications.

KEY MESSAGES

What is already known on this topic

Virtual reality (VR) technology, consisting of computer simulations to artificially generate sensory information in the form of a virtual environment (VE) that is interactive and perceived as being similar to the real world, is recognized as a novel intervention tool in stroke rehabilitation. Gait training combined with VR training has been shown to be more effective than time dose-matched training without VR in clinical measures of gait and balance in people with subacute stroke. Although VR offers the opportunity to create unique and customizable interventions that are not available or readily accomplished in the real world, its clinical implementation may be challenging, especially for chronic stroke survivors who have not recovered the capacity to ambulate in the community.

What this study adds

We have developed a unique, VR-based gait-training system to simultaneously target both the physical and the cognitive components of gait, such as planning, decision making, and self-efficacy—all of which are important determinants of community ambulation for chronic stroke survivors. VR-coupled treadmill walking simulates walking in a rich and changing environment, thereby meeting the demands of community ambulation. This proof-of-principle study shows that a subject walking on a VR-coupled treadmill on a movable surface while immersed in an ecologically valid VE can experience enhanced mobility and self-efficacy; these results can improve the individual's locomotor adaptations, which can then be transferred to real-life situations. Cognitive processing with VR intervention is not necessarily demanding; this was shown by our subject with chronic

stroke, who did not require more time throughout the training duration, compared with treadmill walking alone, to adjust to the demands and complexity of different VEs.

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APPENDIX

Personal Appraisal Questionnaire

Question 1: Have you noticed changes in your walking ability?

- Claims that he has better balance, that he steps with more assurance and walks more naturally. He knows that he can because he could do so in VR training in different situations.
- His brother-in-law, with whom he worked in his yard, found that he walked better on uneven ground and on slopes.
- He could rake and pick up leaves without problem and moved about his yard with more ease without his cane. He noted that he depends less on his cane when he walks outdoors.
- When he goes for walks, he varies his rhythm and can walk faster. He no longer fears walking on uneven surfaces or where there are stones.
- He proceeds without worrying like he used to; he has gained a lot of confidence. He is no longer afraid to walk on carpets and claims that he is more solid when walking on all kinds of surfaces.
- When he had to climb a flight of stairs without a handrail, he did not panic; he was confident and knew how to manage. He examined the situation as he had learned to do in VR training . . . to plan what he had to do. . . . He could find a strategy to climb the stairs without a problem.
- Same thing for crossing a street . . . he could choose a strategy, not panic and adapt accordingly. First, he told himself that he would follow the woman who was crossing the street beside him; when he saw that she walked faster than him, he did not panic, but continued, and when the light signal began to flash, he could walk faster and cross the street in time.

Question 2: What was the added value of the VR training?

- At night, he thought about what he had practised, what he was told, and how he would manage the next time he faced similar situations. "I review the situations and plan my strategies."
- He reviewed his strategies and thought about how he could use them in his daily life.

Question 3: Could you have achieved the same results by practicing in real life?

- "No. VR training shows us that we can do things that are more difficult and that we fear without danger because we wear a harness; thus, we dare to do more because we know that it's not dangerous." "When we manage to do more without failing and without problems, we develop self-confidence."
 - "Because of that, we dare to do more in real life, but, especially, we have learned to evaluate dangers and risks. We know what to pay attention to. It develops our capacity to make decisions." "It helped me prepare for my driving exam."
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VR = virtual reality.