Crowd simulation for vestibular therapists

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Abstract

Crowd simulation can be used by vestibular therapists to help unstable patients to cope better in real crowd situations. Exceptional conditions are required for the simulation. A corner free projection room and high performance "crowd engine" software are necessary. The difficulty to cope in crowds is analysed for three groups of patients, before and after a series (±15) of rehabilitation sessions using crowd simulation. An evaluation ruler is created in order to do so. The patients in all three categories experienced significant improvement.

Keywords: Vestibular rehabilitation, crowd simulation, engine crowd, projection room, imbalance.

1) Introduction:

Context: Dizziness and balance disorders have become a major public health problem as a result of an aging population. Specialised therapists working with people suffering from instability and dizziness since 1989, have long since understood that their patients are unable to cope visually when in a crowd situation.

The "phobia" aspect of crowd situation difficulties has been largely studied in international literature [1] [2] [3] [4] [5]. Behavioural aspects, patients suffering from disease and elderly people, have all been studied in virtual reality situations [6] [7]. However, this appears to be the first time that crowd simulation is used for specifically vestibular problems. Crowd simulation used during vestibular rehabilitation is an innovative technique.

Techniques and evolution: Vestibular therapists treat patients suffering from unbalance for various reasons. One of the therapeutic techniques developped by Alain Semont [9] [10] is optokinetic stimulation (Figure 1), using the entire visual field. Moving spots of light are projected in a darkened room [11]. www.vestibulaire.com

These patients are often unable to cope in crowd situations, although they do not suffer from crowd phobia. Patient grievances experienced in crowded situations are as follows:

"I feel as though I'm going to bump into them"

"I can't cope with the situation"

"It's worse when the others are going in the opposite direction"

"I feel bad when I reach a certain speed"

"It's worse when I'm walking"

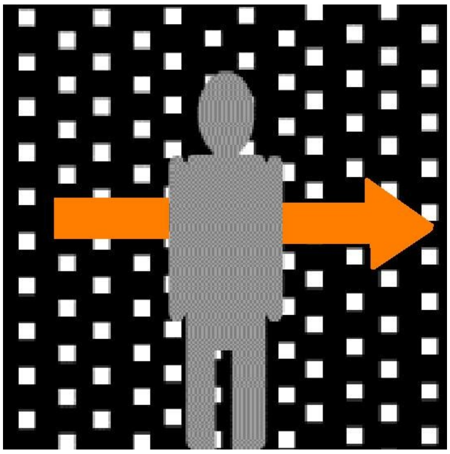


Figure 1: Optokinetic stimulation

"I don't have enough time to analyse the situation"

"I need straight buildings to fix a landmark"

"If someone leans over in front of me I feel lost"

As the ophthalmologist Dr Patrick Quercia, the vestibular physiotherapist noticed the "abandoned trolley syndrome". People suffering from crowd and noise, abandon their trolleys and leave the supermarket. Supermarket directors contacted during a small telephone survey confirm that abandoned trolleys are found several times a week, but generally during busy periods and for these very reasons.

This study is the result of 7 years work using an innovative technique, and crowd simulation has graphically improved over the years.

Here is the first crowd simulation technique which was first used in 2002 (Figure 2).

Figure 2: The "Citywalk" exercise.

Figure 3 :Pressure on the platform

The patient controls his moving in the crowd using the pressure of his feet (Figure 3) and must avoid touching other pedestrians. The physiotherapist programs the crowd density best adapted to the patient.

In search of optimal conditions, in 2005, a made-to-measure projection room is ordered (Figure 4, 5). It has no corners and a domed ceiling (Figure 6).

Figure 4: Metallic structure

Figure 5: Construction. Outside view

Figure 6: Construction of the domed ceiling

It features two flat walls and semi-circular sides (Figure 7). The visual scene can be projected on the flat surface or the 180° surface (Figure 8). Using a very wide angle projector it is possible to create an optokinetic stimulation under optimal conditions, never achieved before. It is fundamental to recall that for optokinetic stimulation to be efficient the entire visual field must be used in order to stimulate the peripheral retina (+180°). In the corner free projection room, "Biofeel software" is used to create varied visual stimulations without a crowd. What is more, it is now possible to project real-size people in this room. But optokinetic stimulation and crowd simulation are two very different techniques. Their therapeutics aim are enterely differents.

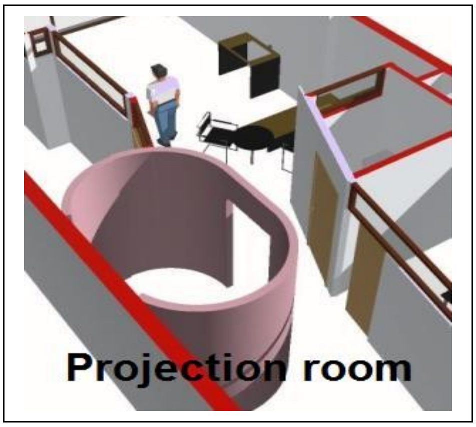


Figure 7

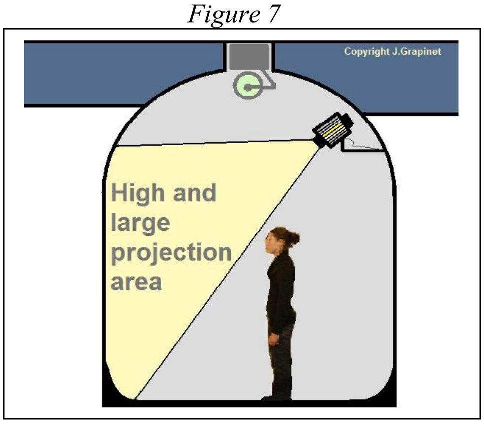


Figure 8

In 2007, along side Citywalk, the crowd simulation system, the use of YAQ software developed by VRLab of the EPFL begins.
The aim is to use the 4th **"crowd engine",** created by the lab, under the exceptional conditions produced in the specialist corner free projection room (Figure 9-10). Under these exceptional working conditions it should be possible to establish which patients suffer in crowds.

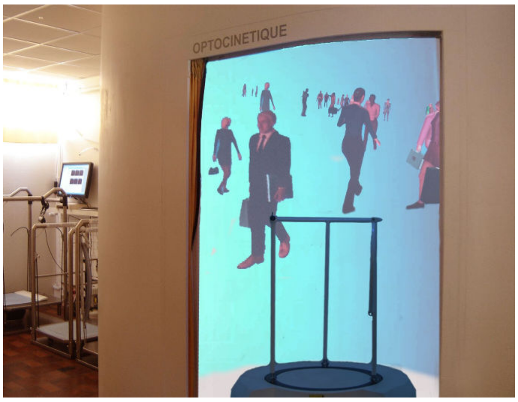


Figure 9: Blue background.

Figure 10: In the dark projection room. Here: Black background on curved wall.

<u>Study target:</u>
This study shows that crowd simulation therapy can help certain categories of unstable patients to visually confront a real crowd situation, and improve vestibular rehabilitation or motor balance results.

2) Study group and method:

Study group: 42 patients, divided into 4 groups, experiencing visual difficulties in crowd situations, are treated by a vestibular therapist[1] in a specialised clinic in Besançon, France:

1) Patients suffering from vertigo due to a long term unilateral vestibular loss caused by vestibular lesion (Figure 11: part of the inner ear which detects ear acceleration), such as neuritis or skull fracture.
2) Elderly people suffering from instability for at least one or two years.
3) Unbalanced patients suffering from non-progressive neurological lesion.
4) Patients whose cerebral vascular accident has affected their balance centres and in particular their visuo-vestibular interactions.

Figure 11: Inner ear or labyrinth, containing the vestibule.

Inclusion criteria: Only patients suffering from unbalance on a daily basis are accepted.
Exclusion criteria: Patients suffering from progressive neurological disorders are excluded to avoid aggravating their functional state. Patients suffering from crowd phobia are identified during a short interview and are excluded.

<u>Methods:</u> Several evaluation methods used by the vestibular therapists are tested on patients between December 2007 and September 2008, in order to evaluate the effects of crowd simulation on:

- The patient's visual comfort in a real crowd situation.

- The patient's overall balance:

  Balance evaluation methods:

1) Foot prints to compare the distribution of foot pressure, initially without crowd simulation, then during crowd simulation *(Figure 12)*.

2) Evaluation of active stability limits on a posturo-sequential platform before and

after the series of crowd simulation sessions (Figure 13).

3) Motor balance measurement by hexa-sequential analysis under 6 conditions, using Equistab (a platform mounted on an air cushion), before and after the series of crowd simulation sessions (Figure 14).

4) Wavelet tests, before and after the series of crowd simulation sessions (Figure 15).

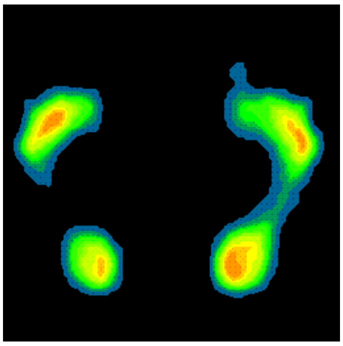


Figure 12: Foot prints

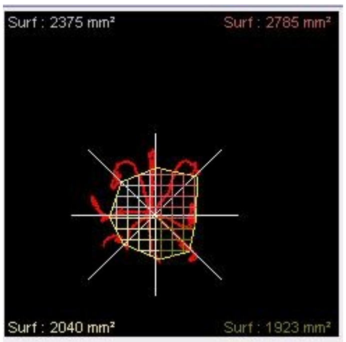


Figure 13: Stability limits

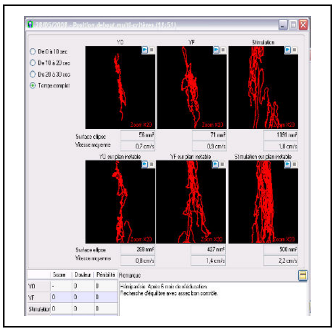
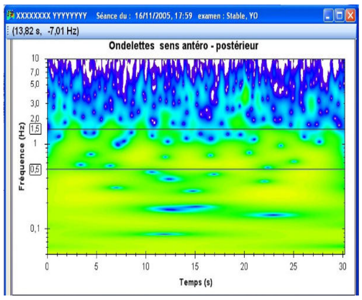


Figure 14:Motor balance measurement



(Figure 15) Wavelet tests

- As no simple method exists to evaluate visual discomfort in a crowd, a visual analogical pain scale is adapted to create a "visual analogical difficulty scale" (VAS) (Figure 16).

The VAS is validated in French. It is recommended by the High Authority of Health in France. The patient positions a pointer on a ruler graded from "zero difficulty" to "impossibility" in order to quantify his difficulty to cope in a crowd (Figure 16). The therapist notes the numerical result shown on the back of the ruler (Figure 17). The ruler is used before and after the series of crowd simulation sessions.

Over a period of two months, each patient attends twelve to fifteen sessions which last 8 to 15 minutes. Sessions never take place two days in a row.

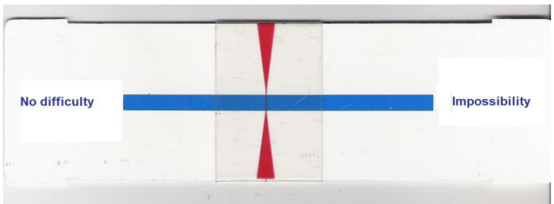


Figure 16: Side for patient

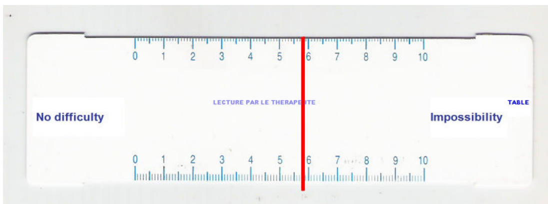


Figure 17: Side read by the therapist

In the descriptive statistical study, average scores are calculated before and after crowd simulation sessions for each group. EPI-INFO is used to compare the average scores between groups. The "Student test" is used if there are less than five members in a group. When the patients VAS score exceeds 5, his discomfort in crowd situations is considered to be intense.

3) Results:

42 patients are used in the study:
1) 19 patients suffering from long term vestibular deficit or long-term inner ear disease.
2) 15 unstable elderly people.
3) 4 unstable patients with non-progressive neurological lesion.
4) 4 young adults suffering from after effects following a cerebral vascular accident.

No significant result emerged concerning the 4 methods measuring motor balance.
The following graphic (Figure 18) and table show the statistical results concerning visual discomfort in crowds, measured using the VAS, before and after crowd simulation (CS). As groups 3and 4 have less than 5 members they are assembled under the heading “non-progressive disorders concerning the central nervous system, including CVA”.

The graphic shows that each patient scores 5 or more before the visual crowd simulation test. This confirms that only people at risk were used for the study.

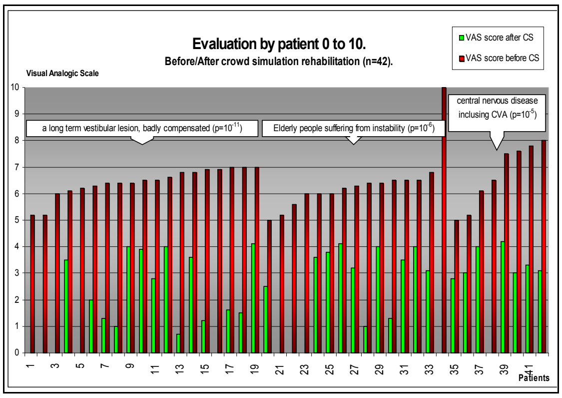


Figure 18

Table 1 (figure 19) shows that the 3D crowd simulation test significantly improves ($p \leq 10^{-5}$) visual comfort in crowds for the 3 groups. Due to the different number of patients in each group, it is not possible to conclude that any one category of patients has better results after crowd simulation than another.

Table 1 : Comparison of the AVS average scores between groups of pathologies

Groups of pathologies	n	AVS score before FS (m±SD)	AVS score after FS (m±SD)	Student 's test ($p \leq 10^{-5}$)
A long term vestibular lesion, badly compensated	19	6,4±0,5	1,8±1,6	3,38E -11
Elderly people suffering from instability	15	6,4±1,1	2,3±1,7	1,93E -06
Non progressive diseases concerning the central nervous system including Cerebral Vascular Accident (CVA)	8 (4)	6,7±1,2	2,9±1,3	1,38E -05

Figure 19

4) Discussion:

This study shows that “crowd simulation in full visual field”, carried out under optimal conditions, is effective for unstable patients who have difficulties coping in a crowd situation, although not suffering from crowd phobia. No comparison to other literature references is possible for there isn’t any study on the topic [1–7]. One prefers not reasoning in terms of posturography or sensorial inputs [8], but in terms of visual comfort. What is more, a patient moving in a crowd probably experiences conflict between visual perception and action. The brain should eliminate useless information and retain that which is required to complete the action being carried out.

In order to reproduce decent conditions for crowd simulation it is necessary to:

1) Respect a certain procedure concerning stimulation conditions:
   a. During the projection, only pedestrians should be visible as roads and buildings represent vertical or horizontal visual landmarks. It is better to project the figures on a black surface in a dark room so that they are represented actual size.
   b. The projected crowd must not be passive, but the point of view must move horizontally as for a person walking in a real crowd.

c. Gradually patients get used to the sessions and experience less discomfort. However, extreme care should be taken when using this type of virtual reality and the patient's reactions (nausea) must be carefully monitored throughout each treatment session.

2) Distinguish between patients suffering from phobia and patients suffering from visual difficulties in a crowd. This is why a preliminary interview is necessary. Using several simple questions a patient suffering from crowd phobia can be distinguished from one unable to cope with rapid and random visual stimulation. During interviews, CVA (Cerebral Vascular Accident) patients, all between 22 and 41 years old, appear to be those who experience the greatest discomfort in real crowds. They are also those who expect the most from rehabilitation.

It is costly for a therapist to reproduce optimal conditions for crowd simulation. 3D crowd simulation software is necessary (presently EPFL YAQ at prototype stage), as well as a very wide angle video projector, and a made to measure room at least 3×2 metres and without angles. The cost of which amounts to at least 10 000€.

5) Conclusion:

A further study using a higher number of subjects would consolidate these results. It is important to include the same number of patients in each group. However this work can only be carried out on a greater scale with collaboration between colleagues able to create the exceptional conditions required for crowd simulation.

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