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Augmented Reality Musical System for Rehabilitation of Patients with Duchenne Muscular Dystrophy

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1. Introduction

Human activity is the centralizing and guiding element in construction of the therapeutic process. According to Carlo e Bartalloti (2001), the human activity is constituted by a group of actions that present qualities, demand capacities and establish internal mechanisms for its accomplishment. Therapy then can be understood as life production, which implicates in a multiplicity of interventions.

This therapeutic multiplicity demands a variety of activities that request resources and diversified techniques. In this sense, computers can aid and support several therapeutic exercises, because they provide knowledge and experiences that run into the interests and needs of each patient, providing new possibilities and purposes in intervention (Watanabe et al, 2003). Computers can offer countless benefits to disabled individuals, as for example, communication easiness, personal growth, autonomy, social interaction and cultural inclusion.

Computers make it possible to create applications for therapeutic use adapted to the patient. The individualized treatment can be executed several times without putting in risk patient's safety. Several variables can be modified seeking to increase or to reduce the complexity of therapeutic exercises (Sveistrup, 2004). Besides, the therapist can supervise the treatment progress, quantify evaluations and adapt the treatment plan.

Technological evolution is allowing that computational system answer to touches, gestures and voice. The computer external environment can be captured by hardware through specific software aided by devices as cameras and sensors. Virtual and augmented reality are examples of technologies that make possible to create differentiated virtual environments to disabled users by using conventional devices as keyboard and mouse (Garbin et al, 2006). Through augmented reality, for example, it is possible to add virtual elements in the real world that can be manipulated in a natural way, with the hands, without use of electronic devices for interaction. This characteristic of augmented reality can provide to individuals with low mobility, access to virtual environment facilitating the education and therapeutic procedures with use of computers.

In literature, several works can be found that make use of a virtual and augmented reality environment in treatment of cognitive and motor disorders (Sveistrup, 2004), (Carvalho et al, 2008), (Richard et al, 2008). However, no work relating technologies with music (applied to rehabilitation treatment) were found to the date of publication of this book. For this reason, for an experiment about use of an augmented reality musical environment (developed to rehabilitation) to be presented, it is necessary to discuss the main differences between virtual environment and mixed environment, pointing their advantages and disadvantages in the therapeutic process. Soon afterwards, a discussion is presented around the possibilities of use of virtual and augmented reality environment in several therapeutic modalities, shown through examples and practical experiences.

Then, a case study will be presented with the augmented reality musical environment GenVirtual applied in rehabilitation of individuals with muscular dystrophy. GenVirtual makes possible to add in the real world, virtual elements capable to simulate sounds of several musical instruments like: wind instruments, strings and percussion. Sounds are played touching virtual elements with hands, without use conventional devices of interaction (mouse, keyboard and joystick) and adapters (to people with physical disability). This way, an individual with hypotonic hands, for example, can use GenVirtual to develop their musical and therapeutic activities. Usually, these individuals cannot keep their fingers bent over the keyboard, or they don't possess enough muscular force to play a tambourine.

Besides resources for musical composition, GenVirtual offers a game of follow sound-and-colors, designed to stimulate attention, concentration and memorization of colors and sounds. Besides cognitive aspects, GenVirtual can provide motor learning through the planning of motor action previously done by the therapist. We hope that the patient can use GenVirtual at home to complement the activities of rehabilitation due to the low cost of this software. With household use, we hope that this software can motivate the family to participate in therapeutic home activities, contributing to their social integration and thus improvement of life quality.

GenVirtual has been evaluated (for specialists in rehabilitation) and experienced (with individuals with motor and cognitive disability) in the Occupational Therapy Division of the Brazilian Association for Muscular Dystrophy (ABDIM). The benefits that GenVirtual offers to therapists and patients with Duchenne muscular dystrophy are being documented and the partial results of this research will be here presented.

It should be noted that this technological introduction doesn't implicates in new theoretical approaches to medical therapies (Carvalho et al, 2008). The objective is to potentiate treatments already existent and to expand the usefulness of techniques already used. This way, the therapeutic relationship and the pertinent use of techniques already established are preserved. As well as other available strategies to the field of therapies, the use of virtual and augmented reality shouldn’t be discriminated, but coherent with patients' needs. For this reason, it should be enhanced the importance of studies in this area that point indications of use of this tool.

2. Mixing Real Environment with Virtual Worlds: perspectives and therapeutic implications

Virtual reality environments make possible total immersion in an artificial three-dimensional world (Kirner & Tori, 2006a). This way, the user can explore and manipulate imaginary virtual worlds as if they were being part of him. Images generated by computer seem to be natural size and scenery modifies starting from the user's interaction with the virtual world. If environment incorporates three-dimensional sounds, then user is convinced the orientation sounds change naturally in agreement with his/her orientation inside the environment. The immersion in a virtual world can be provided through specific technology (Burdea & Coffet, 1994): head-mounted displays (HMD), devices of optical tracking, force-feedback data gloves and joysticks that allow the user to navigate inside a virtual world and to interact with virtual objects (Fig. 1).

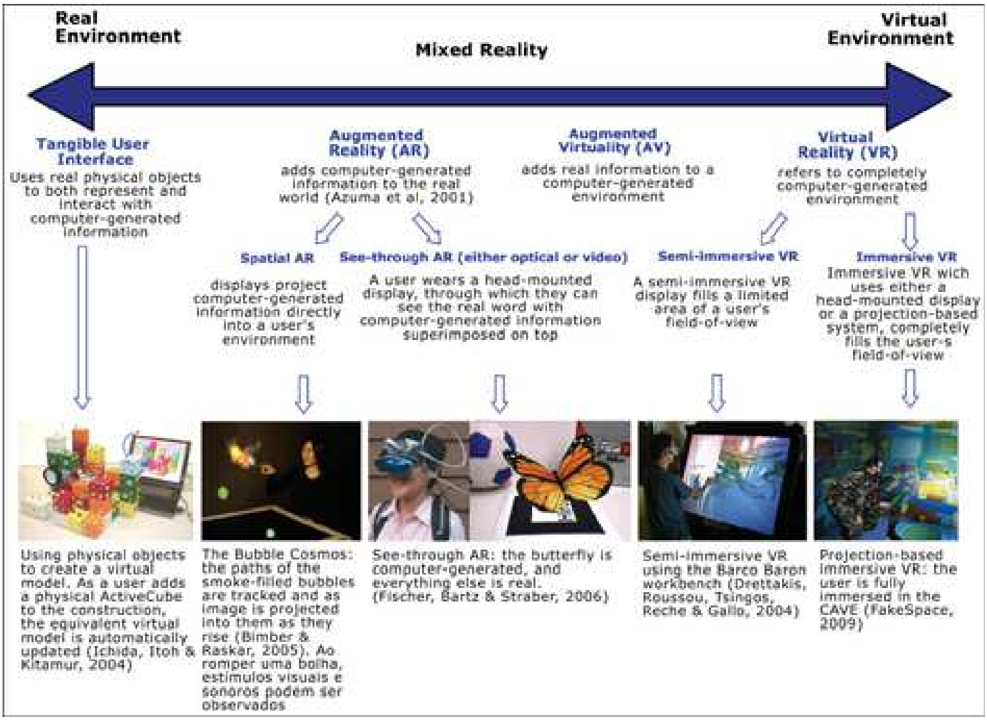


Fig. 1. Continuum of advanced computer interfaces based on Milgram and Kishino (1994).

From the appearance of virtual reality, there was always a separation between real and virtual world. However, technological progress has made possible to mix real environment and virtual worlds (in real time) originating a new concept denominated mixed reality (Kirner & Tori, 2006b). Unlike virtual reality that transports the user inside a virtual world, mixed reality propitiates the incorporation of virtual elements in real environment (the user maintains the presence sense in real world) or it transports real elements for virtual environments complementing the environment. When there is predominance of real over virtual, the environment is characterized as augmented reality; therefore the real environment is enlarged ("augmented") with addition of three-dimensional objects (Fig. 1). To the opposite, when there is predominance of virtual over real, the environment is characterized as augmented virtuality; therefore real physical objects are captured in real time and inserted in simulated environment by computer.

Augmented reality presents a great advantage on augmented virtuality: allows transport of virtual objects to the real world providing new interaction possibilities to individuals with serious problems of fine motricity (ability) and global motricity (agility). In this case, that the user can manipulate virtual objects happens in a natural way, dragging or touching an object with his/her hands or with his/her feet, without necessarily using devices for interaction or adapters. In case of augmented virtuality or even of virtual reality, training is necessary to use appliances as mouse, keyboard, joystick or other technological devices. Many times, that need generates indifference, fear or even individual's incapacity in interacting with virtual environment.

Augmented reality tends to use devices less perceptible to users, seeking to provide larger naturalness of their actions through tangible interfaces (Azuma et al, 2001). According to Leitener et al (2007), a tangible interface allows manipulation of virtual objects with hands or through physical devices similar to the virtual object. In that way, tangible interfaces unite advantages of physical manipulation and innovative forms of interaction provided by computation, thus enriching the experience of individuals with learning deficiency.

A lot of times, to attend specific needs of individuals with deficiency it is common to develop adaptations for use with computational systems. In function of a specific problem, some individuals can need specific resources hindering the therapeutic process, causing, besides, a higher cost for conception and use. Through tangible interfaces, for example, it is possible to build augmented reality environments, economically viable compared other virtual reality environments. With use of a computer (to process software), a webcam (to capture real environment), a monitor (to visualize mixed environment) and pieces of paper with letters printed on them to create tangible objects, it is possible to develop a simple augmented reality environment, but with a variety potential applications to work with individuals with different deficiencies and incapacities (Garbin et al, 2006).

Presence of a register (paper marker) in the field vision webcam enables the virtual object associated to this marker to be superimposed on it. Manipulation marker in real environment also moves the virtual object: if the individual drags the register with his/her hands, the virtual object associated to that marker is moved together. Besides virtual objects, sounds can be initiated when marker enters in the webcam vision field. Some markers can be created to interfere in associated objects with other markers, making possible to accomplish geometric alterations, change objects, capture or duplication, deletion, etc. Like this, virtual objects can be altered or replaced in agreement with needs, interests and abilities of each individual, generating experiences differentiated with the construction of different sceneries.

This characteristic of augmented reality facilitates the communication process of children with learning difficulties; besides this, allows motor and intellectual development. According to Piaget (1995), cognitive development can be explored through symbols and abstractions of reality, favoring for better understanding of the situation problem and results. In augmented reality environment, children can explore these abilities through

composition; alteration or creation of new situations driven through their autonomous actions impelled by their desire and imagination.
Motricity in an augmented reality environment can be worked through manipulation of tangible objects. This activity can contribute in an expressive way in formation and structuring of the sensorial-motor control, being characterized as education that is done through movement, so that the individual acquires functions more and more elaborated and complex (Leitener et al, 2007). Through this dynamics it is wanted that the individual notices his/her potentiality and identifies the interaction possibilities in augmented reality environment, aiming to overcome harmful subjects in psychomotor development.

3. Used Forms of Virtual and Augmented Reality Environment in Therapeutic Process

Virtual and augmented reality has been used to support medical therapies in a variety of proposals. High degree of realism simulated sceneries for computer and the possibility of mixing real environment with virtual one offer new treatment possibilities to individuals with different deficiencies and incapacities. Among the most common therapies, accomplished with use of virtual reality, considering the context of conducts, can be mentioned live exhibition, that consists of exhibition of the individual to the real situation of his/her phobia, and imaginative, in which the individual imagines the objective of his/her fear in the therapist's clinic (Carvalho et al, 2008). In these cases, fear condition can be introduced to the patient in a virtual way and not in a real way as in conventional treatment. So much in live exhibitions as in imaginary, it is necessary to build with the patient a list with the hierarchy situations and fearsome stimulus. Starting from that, it is possible to create sceneries with situations and incentives corresponding to reality. The fearsome stimulus are lived in a virtual environment that allows interaction, making it possible to the patient to act in sceneries just as in a real environment (Carvalho et al, 2008). The presence feeling experienced by the patient in a virtual environment and the sensorial-motor involvement (proportionated by different sensorial incentives) provide a larger reality sensation than the individual could feel when constructing sceneries of his/her own imagination (Carvalho et al, 2008).
In the literature can be found works verifying the effectiveness of the virtual environment in treatment of several phobias (Medeiros, 2006). Hoffman et al (2003) investigated the applicability of virtual reality in spider phobia treatment. Juan et al (2005) tested augmented reality environment in individuals with cockroaches and spiders phobia. Results of this researches showed that individuals that received treatment through virtual environment obtained significant improvement, compared to individuals that received conventional treatment.
The main advantages of the virtual treatment of phobias are easiness and variety (North et al, 1998). The enormous range of phobias that can be simulated through virtual and augmented reality explains this variety. The easiness is applied in some phobias that are difficult to be presented in real way, for example, fear of flying. This environment can be easily simulated through virtual reality.
Several works about use of virtual environment for cognitive rehabilitation were found in literature including applications turned to treatment of feeding disorders (Riva et al, 2000), autism (Parés et al, 2005), traumatic cerebral lesions (Bodine & Scherer, 2006), cerebral palsy

(Reid & Campbell, 2006) and also prevention of accidents with senior patients (Alpini et al, 2000). Effects generated by virtual environment stimulate plastic changes in brain, essential for the rehabilitation process, for example, the ARVIC project: virtual integrated environment for cognitive rehabilitation (Costa e Carvalho, 2001).

ARVIC is a virtual reality environment developed to train attention, memory, planning and calculation through recognition of monetary symbols (notes and coins) associated to the products' prices. Environment is constituted of a city containing parkings; stores and a virtual supermarket in a way to mirror situations lived by users in their day-by-day. In ARVIC environment the user can previously buy goods with an amount of money and a list of products established. Products of virtual stores appear located in shelves with price indication in the currency of Brazil. Individual navigates in the virtual world using a mouse for interaction. When clicking with the mouse in a chosen product, a new window opens up showing the user a variety of notes and coins. The user then should choose the exact money amount to accomplish these purchases, considering the amount in money available and the list of items supplied for purchase. ARVIC was tested with several individuals with different pathologies, among them schizophrenic (Costa e Carvalho, 2001) and people with brain lesions (Cardoso et al, 2006). The clinical results proved the effectiveness of this tool in cognitive functions rehabilitation (attention, memory, planning and calculation), verifying patients' most satisfaction with use of a virtual environment to learn.

Another relevant work for cognitive rehabilitation is ARVe (Augmented Reality applied to Vegetal field) (Richard et al, 2008). ARVe is an augmented reality environment (applied to Biology area) for rehabilitation of cognitive disabled children. The virtual environment is constituted of a book containing several registrations (symbols) glued in pages book. Each symbol represents a vegetable component (leaves, flowers, fruits and seeds). The objective is to organize the vegetables components in agreement with their functions. For example, the child should contain all fruits in a book's page, all seeds in another page and so on. Visual cues (red or blue virtual circles) are used to help the child carrying out the task.

Virtual games also present a space of cognitive development exploring basic cognitive functions, such as attention, concentration, memory, planning and calculation, space ability, among other activities that keep relationship to those accomplished in day-by-day (Costa e Carvalho, 2005). Starting from challenges created through games, brain is stimulated to create nervous cells that help to restructure harmed areas. Besides, games can be suitable for different goods, ethnic and age groups and easily they can be found and handled in different contexts as school, clinical hospital, home and other.

Games in augmented reality, for example, allow enriched vision for user and enlarged environment, stimulating perception capacity and space reasoning. Zorzal (2006) presents several models of puzzles games created with augmented reality, for example, game of Words. In this game, markers are cards containing several letters. The user should group the letters to build words that are registered previously in game. When user forms a sequence of letters (registered word), it is possible to visualize a virtual object regarding that word. This characteristic makes this game a source of practical applications like literacy, learning of languages, besides making possible the development of cognitive abilities.

3.1 Motor Rehabilitation Facilitated by Virtual Reality Games

Great rehabilitation centers in the world began to implant its units of virtual rehabilitation whose focus is in computerized games use for intensive rehabilitation (Deutsch et al, 2008), (Burdea et al, 2008), (Halton, 2008). Patients that suffered a cerebral vascular accident or went through surgical procedures and also for lesions combat, are being benefitted with use of games as an alternative mean for motor rehabilitation. Usually, this patient needs an intensive physiotherapy, which a lot of times can turn into repetitive and painful therapy for the patient. With spreading of games in therapies, the scenery is other. With a game, patients forget that they are in therapeutic intervention. That helps them getting rid of boredom caused by repetitive movements that involve the process of motor rehabilitation.

Virtual reality technologies have been impelling the conception of several computerized games with new entertainment forms (Burdea et al, 2008). It is case of wii, Nintendo videogame that makes use of a remote controller "*wiimote*" sensor based that captures the movements and players' gestures during the game. Players don't need to seat in front of computers or videogame consoles, limited by a joystick. This game allows players to move and interact in different ways in real environment, through different devices and communication technologies without thread.

This characteristic of wii games has shown to be efficient in process of motor rehabilitation, for being a mechanism that requests sensitive and precise movements, similar to activities in daily life. Those movements are made through games that simulate baseball departures, bowling, boxing, tennis, golf, dances, etc. The effort to execute well the movements can provoke positive impacts in the organism as invigoration of musculature, easiness for recovery movements, incentive cerebral activity and increase concentration capacity and balance.

4. A Case Study with an Augmented Reality Musical Environment in Rehabilitation of Individuals with Duchenne Muscular Dystrophy

4.1 GenVirtual: Conception and Description

GenVirtual is an augmented reality musical environment that allows to develop creation activities, improvisation and musical reproduction such as composition and reproduction of melodies, listening to musical and sounds, and musical memory games.

GenVirtual allows to add to the real world, three-dimensional virtual elements (colored cubes) capable of simulating sounds of several musical instruments like wind instruments, strings and percussion. Sounds are executed playing virtual elements with hands, without use of conventional interaction devices (mouse, keyboard, joystick) and adapters for individuals with low mobility (Fig. 2). Some patients have hypotonic hands and cannot keep their fingers bent over the keyboard or do not have enough muscle power to play percussion instruments. In those cases, adapters are necessary, for example, tips in the hands to play the piano (or electronic keyboard) or a support to the tambourine so both hands can be used.

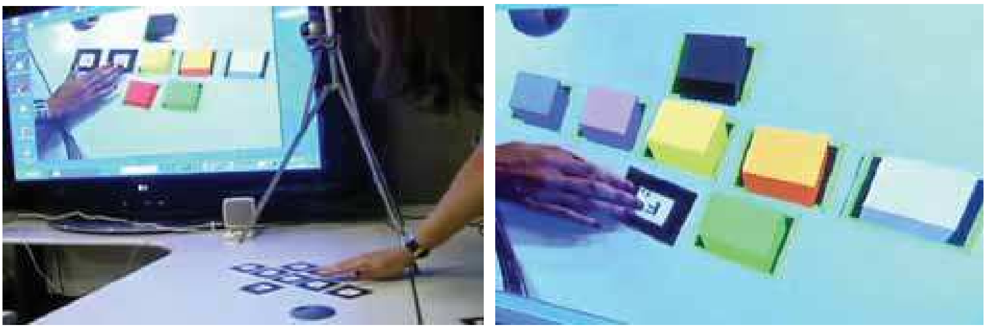


Fig. 2. GenVirtual Interface

Identification of markers (cards) on table happens through processing of images, captured by a webcam, connected to a computer, strategically positioned in the superior part of the table. Symbol card is detected and associated to a sound. The emblem of a piano is the standard sound associated to cards, but there is the possibility to change the emblem of musical notes emitted by cards. For this, simply add a new label in the symbol table containing the desired musical instrument. In this way, same virtual elements emit different sounds, according to instrument defined by new card. It could assume emblems of wind instruments (flute, trombone, trumpet, etc.) or string instruments (violin, guitar, etc). Another possibility is to use cards with symbols corresponding to percussion instruments, as drums, tambourines, triangles, as well as symbols that represent sounds of electronic instruments.

The differential in this music system is the flexibility of cards for interaction. Cards can be printed in different colors and proportions, allowing the therapist to realize a unique motor planning for each individual, in accordance with desired motor challenge. Cards can be organized in different ways on the table, or on the floor, where interaction occurs.

GenVirtual also has a game called "follow sound-and-colors", that makes it possible to stimulate the attention, concentration and memorization of colors and sounds. In this case, GenVirtual generates a musical sequence. Virtual cubes rotate in agreement with the musical sequence to be played, and simultaneously, the musical note regarding that virtual cube is executed. Musical notes are emitted one per time, and system is awaiting the user's interaction that should obstruct the marker regarding the emitted musical note. To each success, sequence wins a new item (musical note), increasing the challenge of memory and retention of information game.

Besides cognitive aspects, GenVirtual can provide the motor learning through the planning of motor action, previously prepared by therapist. According to Nascimento (2006), it is important to have a reference of motor movement to make possible to control movement of that individual, otherwise, motor learning does not occur.

4.2 GenVirtual Implementation

GenVirtual uses techniques of computational vision to generate, to position and to show virtual objects in real world. Basically a webcam (connected to a computer) captures images in real time (video frames). Captured images are analyzed by computational vision software ARToolkit (Geiger et al, 2004). ARToolkit analyzes captured images in search of symbols registered previously by user. Symbols are printed inside a frame in common and organized paper over the table (tangible objects). When recognizing a symbol, ARToolkit calculates its position and orientation in relation to the real position of webcam and shows in display (monitor) the virtual object super imposed to corresponding symbol (visual feedback). Figure 3 shows necessary components to use GenVirtual.

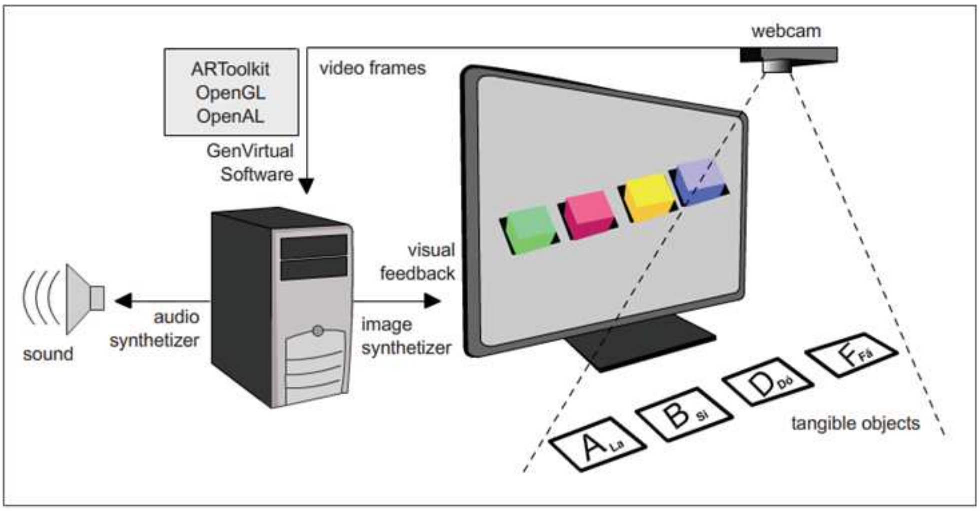


Fig. 3. GenVirtual components

ARToolkit Operation: each video frame captured is transformed in a binary image (black and white) based on an intensity threshold value. Then, it looks in this image for square areas. For each square, the standard drawing inside of it is captured and compared with some forms pre-registered by user. If there is some similarity, ARToolKit considers that it found one reference marker and uses known square size, as well orientation of found pattern, to calculate the real position of camera in relation to real position of marker. A matrix 3x4 will contain real coordinates of camera in relation to marker. This matrix is used to calculate position of coordinates of the virtual camera. If virtual and real coordinates of camera are the same, the graphic computation model can be drawn precisely on real marker. OpenGL library is used to calculate virtual camera coordinates and to draw virtual images. This procedure is illustrated in Figure 4.

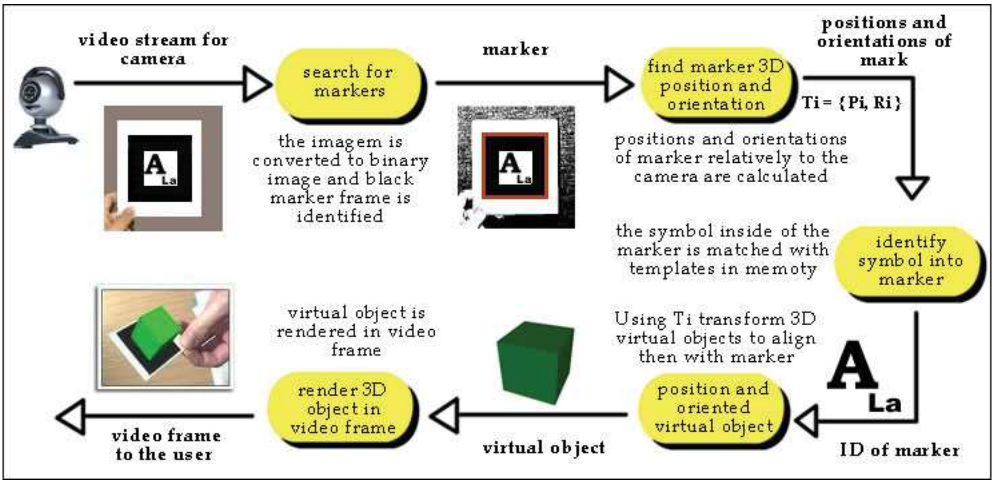


Fig. 4. ARToolkit cicle (Geiger et al, 2004)

Some advantages found in GenVirtual computational vision system:

- Computational vision system can be created in low resolution, making use of just a webcam, which enables a low cost;
- Visualization system is based on monitor or projection screen (indirect vision). Such systems possess inferior cost if compared to other visualization systems as visualization helmets with built-in video cameras;
- Variety of registrations (tangible objects) that allows to diversify musical activities;
- Interaction devices (tangible objects) are easy to use and accessible economically (it can be printed in conventional printer);
- Therapist can create the wanted motor challenge, in agreement with each individual's motor limitation through arrangement of registrations in the table.

4.3 GenVirtual Indications

GenVirtual was applied with patients with muscular dystrophy rehabilitation during occupational therapy at São Paulo Muscular Dystrophy Brazilian Association (ABDIM). The goal was to verify if GenVirtual, applied to a program of superior members exercises, is capable to interfere in motivation, satisfaction and consequent adherence of occupational therapy rehabilitation program of patients with Duchenne muscular dystrophy.

Clinical aspects of Duchenne Muscular Dystrophy (DMD)

Progressive muscular dystrophy (DMP's) form a group of human diseases determined genetically and associated to progressive skeletal muscles degeneration, without compromising central nervous system (Kakulas, 1999). DMP's are characterized by progressive muscular weakness, deterioration and degeneration of muscular fibers, being these of hereditary transmission (Zats, 2002). All of which are characterized equally by a musculature progressive degeneration, whose inheritance can be dominant autosomal, recessive and linked autosomal to X chromosome (Kakulas, 1999). In Brazil, DMP's reach 1 in each 2.000 births (about 100 thousand Brazilians) independent of race or social class.

There are more than 30 dystrophy types, and the more incident and with the worst prognostic is Duchenne muscular dystrophy (DMD) (Zats, 2002), (Stone et al, 2007).
In DMD, clinical signs begin at 3-5 years of age (with frequent falls, difficulties to go up stairways, to run and to get up from ground), retarding normal motor development. Confinement to wheel chair happens before 12 years of age and the affected ones rarely survive after third decade. Studies accomplished in several countries demonstrated a life expectation from 18 to 25 years (Santos et al, 2006). This prognostic has been promising mainly with the introduction of no invasive ventilation (Vianello, 2000). About 30% to 50% of patients with DMD possess mental retardation, whose cause is being investigated (Bach 2004), (Rapaport, 1992).
Muscular compromising is bilateral, symmetrical, proximal musculature is reached previously to distal, and contractures and deformities presence become relentless with natural evolution of the disease (Zats, 2002), (Santos et al, 2006), (Vianello, 2000). These patients start to have a very restricted functional capacity, frequently limited to small mobility of manual extremities.
There isn't any known cure today, or pharmacological treatment that stops or reverts DMP's degenerative process and of a great part of neuromuscular diseases (Santos et al, 2006). In spite of that, there is a series rehabilitation treatment that can stabilize the clinical picture of the pathology, or even reduce the progression speed. Programs of individuals' rehabilitation with DMP present as main purpose to minimize sequels of the pathology, improving quality of life of bearers, through maintenance and prevention of dysfunctions (Zats, 2002), (Santos et al, 2006). For this reason it is necessary to create diversified forms of therapeutic approaches aiming to provide new activities that favor the enlargement of individuals' functional, social, emotional and vocational capacities with DMD.

4.4 Methods

Casuistical: 16 male patients participated in this work, with ages between seventeen and twenty-four. Incorporation of patients to the study depended on authorization of a responsible person expressed through the term of free and illustrious consent. Inclusion criteria were: to possess diagnosis of Duchenne muscular dystrophy; to have accomplished specific rehabilitation program of upper limbs in ABDIM at least for twelve months ago. Exclusion criteria were: to possess some cognitive deficit; illiterate patients.
Participant: 16 individuals with diagnosis of Duchenne muscular dystrophy; they were randomized in two groups, through drawings. 11 patients received exercises programs for active extension of elbow, forearm pronation/supination and wrist extension, using augmented reality resources. Other 5 patients continued accomplishing the active extension of elbow exercises, forearm pronation/supination and wrist extension, using conventional resources of rehabilitation.
Evaluation: using a questionnaire, motivation evaluation and patient's satisfaction - Likert scale (Oliveira, 2001) were measured. In the application of Likert scale, patients indicated agreement degree or disagreement with relative declarations to the accomplishment upper limbs exercises. Punctuation was distributed in the following way 100% (excellent), 80% (very good), 60% (good), 40% (regular), 20% (bad) and 0% (very bad). Questionnaire was applied to the group that used GenVirtual as well as to the group that used the conventional rehabilitation material. Four aspects were selected: 1) easiness of use of GenVirtual or other material during therapy 2) exercise effect 3) motivation degree when accomplishing the

exercise and 4) satisfaction when accomplishing exercise. Therapist's questionnaire was based on three aspects: 1) practicality of equipment use (pre-installation e post-installation) 2) instructions to patient 3) degree of patient's motivation (therapist's vision) when accomplishing exercises.

Intervention: each group received weekly intervention of 30 minutes. Interventions were divided in ten minutes of specific exercises of scapular waist, ten minutes of elbows exercises, forearm and fist wrist and ten final minutes of free activities. Patient stayed positioned at a table, with proportional height of ergonomics of a wheel chair. After the first session a blind evaluator interrogated the patient on his/her satisfaction index. After 4, 8 and 12 sessions the same scale will be reapplied. The same procedure happened with patients of control group that received the conventional intervention, in other words, without using GenVirtual. Therapist's evaluation of technology use was also conducted after the end of each intervention.

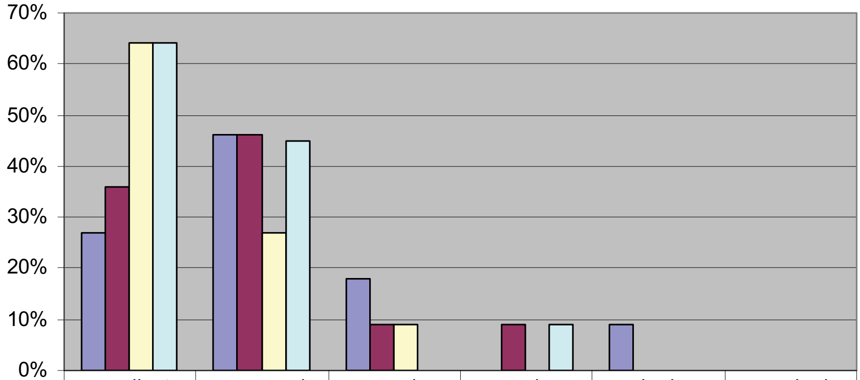
4.5 Results and Discussions

Results here presented are regarding the first intervention. After 4, 8 and 12 sessions the same scale will be reapplied and results will be tabulated again and analyzed for futures publications. Figure 5 shows some images of interventions with GenVirtual accomplished in ABDIM.

Fig. 5. Intervention with GenVirtual in ABDIM

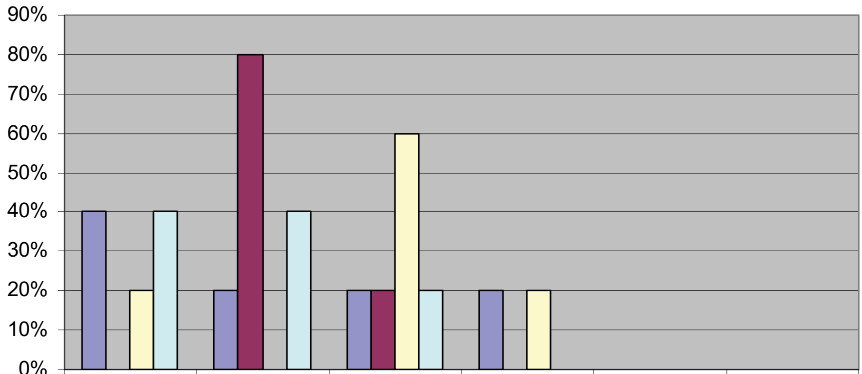
Likert Scale applied with patients

Figure 6 and 7 show results obtained after the collection of 16 participants' data: motivation and satisfaction level of patients when accomplishing interventions, degree of easiness use of rehabilitation instruments during therapy and accomplished exercises effect.



	excellent	very good	good	regular	bad	very bad
Facility	27%	46%	18%	0%	9%	0%
Effect	36%	46%	9%	9%	0%	0%
Motivation	64%	27%	9%	0%	0%	0%
Satisfaction	64%	45%	0%	9%	0%	0%

Fig. 6. Classification levels of easiness, effect, motivation and satisfaction of patients when using GenVirtual in interventions.



	excellent	very good	good	regular	bad	very bad
Facility	40%	20%	20%	20%	0%	0%
Effect	0%	80%	20%	0%	0%	0%
Motivation	20%	0%	60%	20%	0%	0%
Satisfaction	40%	40%	20%	0%	0%	0%

Fig. 7. Classification levels of easiness, effect, motivation and patients satisfaction when using conventional rehabilitation material (without GenVirtual) during interventions.

To proceed they are discussed the four aspect presented in graphs above: easiness, effect, motivation and patient's satisfaction.
Figure 8 shows a comparison among levels of facility of material used during interventions. In the patients' case that used GenVirtual: 27% found excellent, 46% found very good, 18% found good and 9% found bad. In this last case individuals are framed with little mobility and they had a lot of difficulty in obstructing markers.
In conventional intervention, patients used a stick to accomplish exercises of elbow extension (sliding the stick in table with arms) and modeling mass for exercises of fist extension (touching the mass with hands). Exercises with stick and mass they are equal to the same exercises accomplished with GenVirtual, the one that changes are support materials. The level of easiness of this material varied enough: 40% found excellent, 20% very good, 20% good and 20% regular.

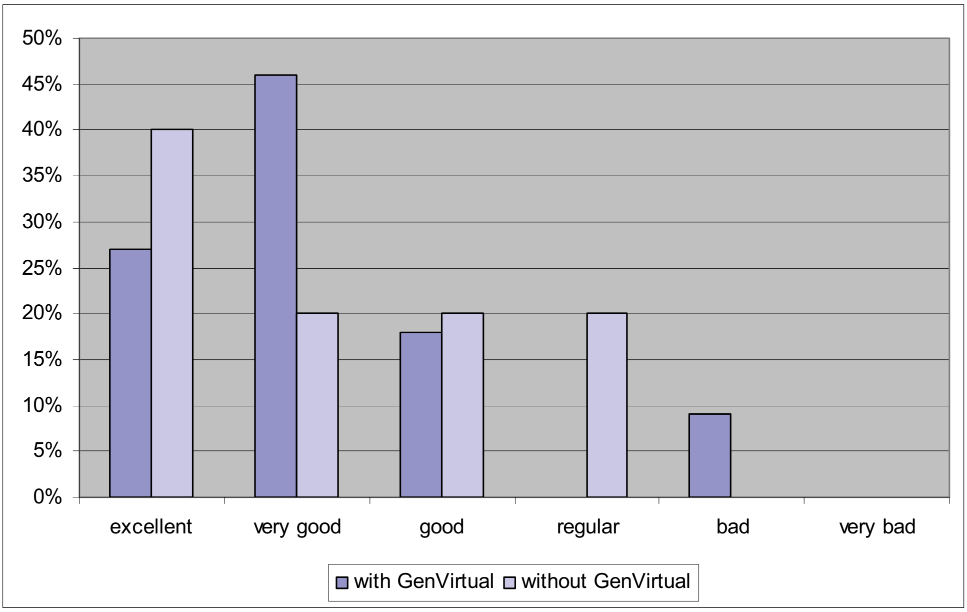


Fig. 8. Classification levels of facility with and without GenVirtual

Figure 9 shows a comparison among levels of effect exercises accomplished with GenVirtual and levels of effect of exercises accomplished without GenVirtual. Results show that effects caused with GenVirtual were proportional to effects caused with conventional exercises: 36% said excellent, 46% very good, 9% good and 9% regular. Negative factor (9% regular) is explained with the deposition of some patient that said that he/she didn’t need strength to execute sounds and as a consequence it was not necessary to dissociate or to extend fingers to move and rotate wrist to obstruct the cards in the table. However, exercises’ objective was exactly wrist extension, which was verified with GenVirtual. In interventions without GenVirtual, the level of exercises’ effects varied among good (20%) and very good (80%).

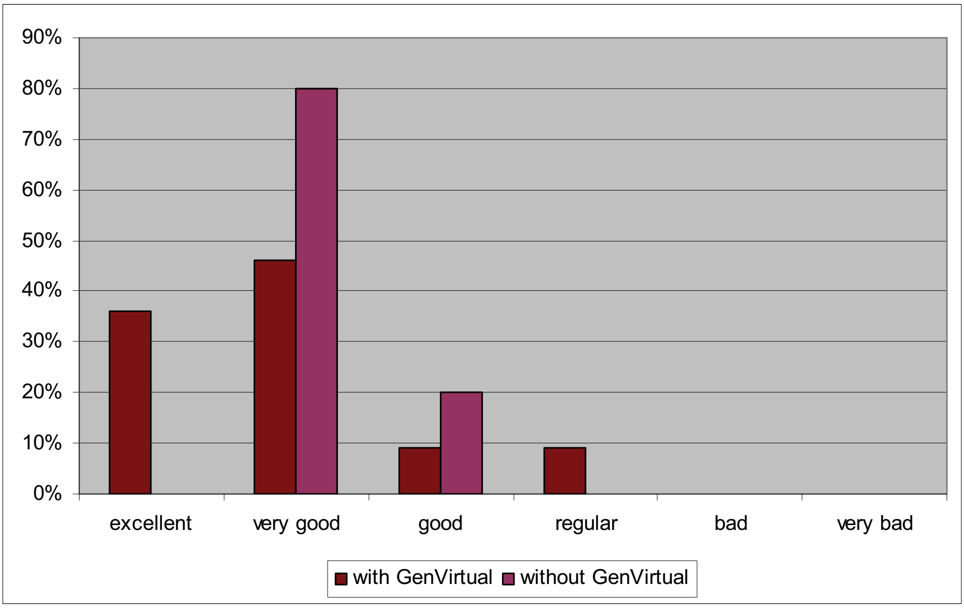


Fig. 9. Classification levels of exercise effect with and without GenVirtual

Figure 10 shows a comparison among levels of patients' motivation that used GenVirtual and the levels of patient's motivation that didn't use GenVirtual. Results demonstrate that motivation level was larger when accomplishing exercises with GenVirtual: 64% of patients said that the motivation degree is excellent, the remaining varied between good and very good. In interventions without GenVirtual, motivation level decreased: 60% of patients said good, 20% found excellent and 20% found regular.

It fits to stand out that results of this experiment in ABDIM are still preliminary and they are just equal to first application of questionnaire Likert. In spite of the fact that all patients use computers, no patient had interacted with an augmented reality environment previously. These patients' first deposition on GenVirtual was positive: all said that environment is very cool, different and stimulating, a different form of doing rehabilitation exercises and that they would like to continue the treatment with GenVirtual. The factor of larger motivation for most patients was the possibility to easily change musical instruments. Many patients wanted to show to their therapist musical knowledge, trying to compose melodies with different instruments.

Figure 11 shows a comparison among satisfaction levels of patients when accomplishing exercises with GenVirtual and levels of patient's satisfaction that made intervention without GenVirtual. Results demonstrate that satisfaction level was larger with GenVirtual: 54% said excellent, 38% said very good and 8% said regular. In interventions without GenVirtual, satisfaction level decreased, however not a lot: 40% found excellent and the remaining varied between good and very good.

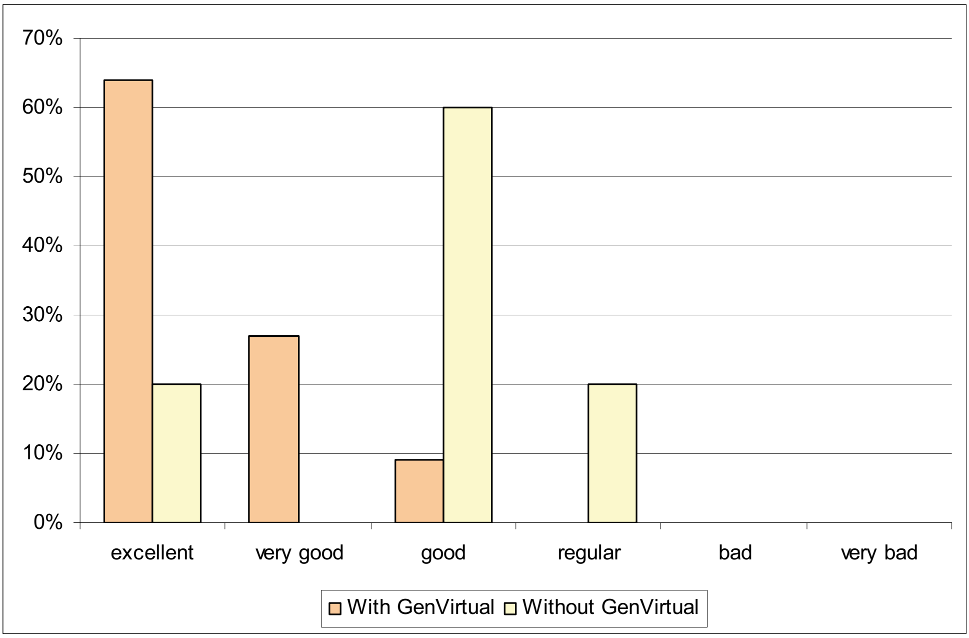


Fig. 10. Classification levels of motivation with and without GenVirtual

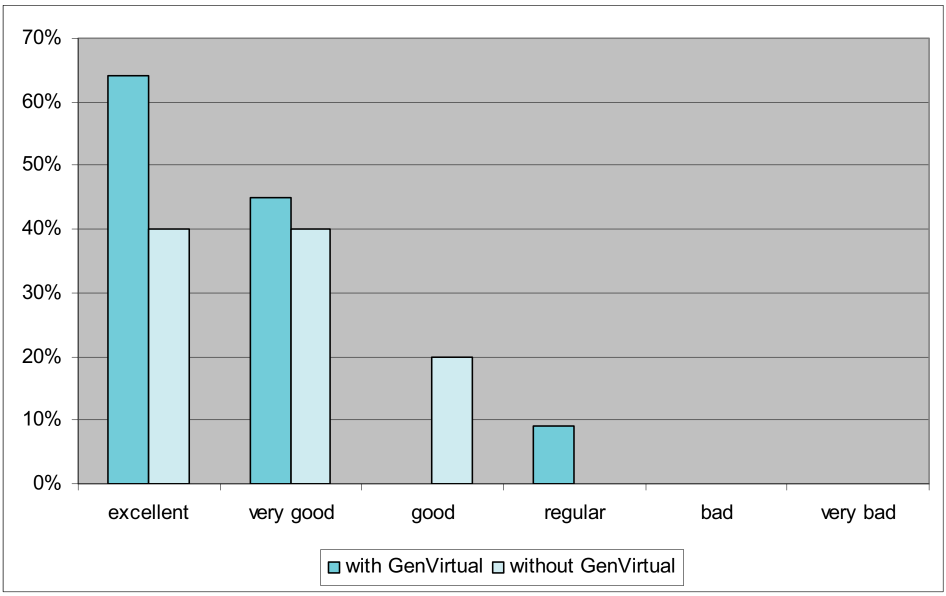
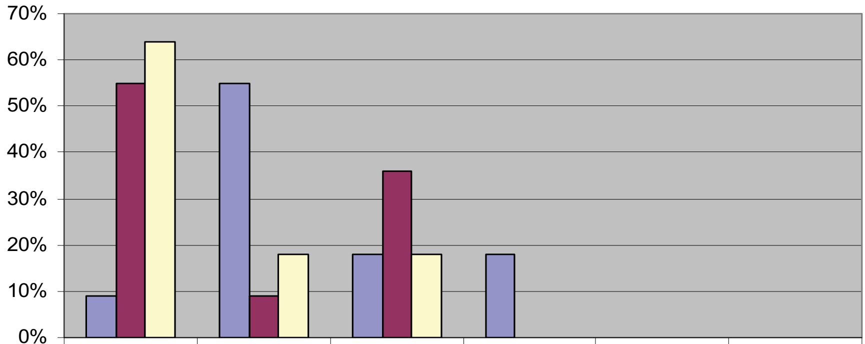


Fig. 11. Classification levels of satisfaction with and without GenVirtual

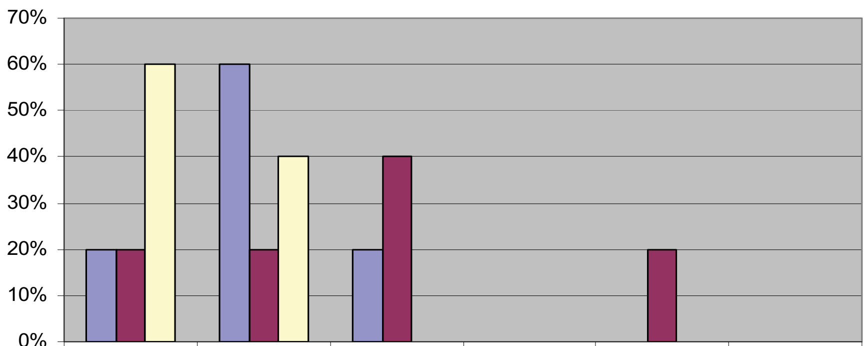
Likert Scale applied to the therapist:

Figure 12 and 13, show results obtained after the data collection of 2 therapists' involved in these interventions. Results show data as: practicality of equipment use (assembly and desassembly), applicability (use instructions) to patient and degree of patient's motivation (therapist's point view) when accomplishing exercises.



	excellent	very good	good	regular	bad	very bad
Practicality	9%	55%	18%	18%	0%	0%
Aplicability	55%	9%	36%	0%	0%	0%
Motivation	64%	18%	18%	0%	0%	0%

Fig. 12. Classification of practicality, motivation and applicability levels of GenVirtual in interventions (therapist's point of view).



	excellent	very good	good	regular	bad	very bad
Practicality	20%	60%	20%	0%	0%	0%
Aplicability	20%	20%	40%	0%	20%	0%
Motivation	60%	40%	0%	0%	0%	0%

Fig. 13. Classification of practicality, motivation and applicability of conventional rehabilitation material (without GenVirtual) used during interventions (therapist's point of view).

Figure 14 shows a comparison among practicality levels of GenVirtual and conventional material (stick and mass) used to accomplish exercises. Process of materials' assembly was taken into account before beginning interventions as well as disassembly process after concluding interventions. Results demonstrate that the practicality level of both materials was very good. Time of GenVirtual assembly was larger than time with stick and mass. This occurred because it was necessary to adjust the table with the webcam and the patient's posture in relation to table. In general Genvirtual practicality as good: 9% excellent, 55% very good, 18% good and 18% regular. And with stick and mass: 20% excellent, 60% very good and 20% good.

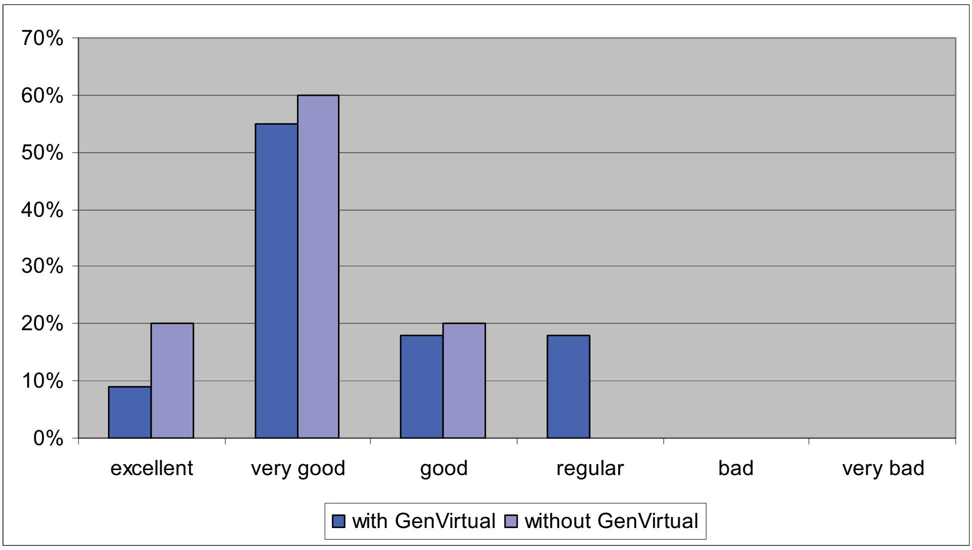


Fig. 14. Classification practicality levels with GenVirtual and with conventional rehabilitation therapy material (without GenVirtual).

Figure 15 shows the comparison among applicability levels of material used to accomplish therapeutic exercises. In case of GenVirtual: 55% found excellent, and the remaining varied among very good and good. Most of therapists found GenVirtual intuitive and of easy assimilation for patients. In case of material with modeling mass and stick: 20% excellent, 20% very good, 40% good and 20% regular.

Finally, figure 16 shows levels of patient's motivation (therapist's point view) when using therapeutic resources in interventions. With GenVirtual: 64% of therapists found patients more motivated during intervention. The remaining varied between good and very good. With use of modeling mass and stick: 60% found excellent and 40% very good. This result demonstrates that the technology doesn't substitute therapeutic practice and yes it complements and it supports already established techniques.

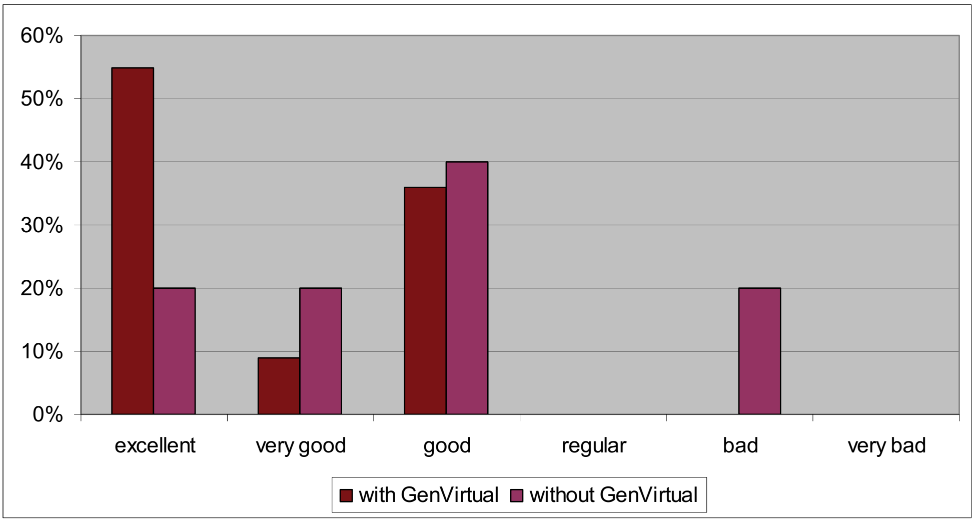


Fig. 15. Classification levels of applicability of therapeutic materials used

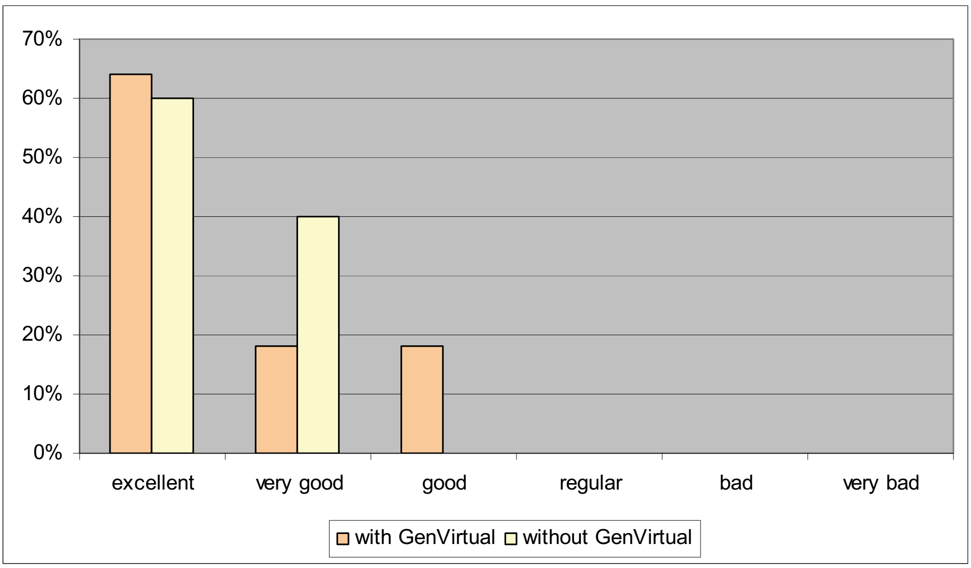


Fig. 16. Classification levels of motivation of the patient's from therapist point of view

4.6 Positive and Negative factors

Some positive points considered:

▪ Larger motivation: most patients demonstrated more motivation to accomplish upper limbs exercises in a different way making, changing the routine of conventional exercises.

- Differentiated exercises: patients that made exercises with stick and mass found them very repetitive, unlike patients that used GenVirtual, that could make same exercises in diversified ways (changing the cards musical notes and musical instruments).
- Musical stimuli: some patients tried to show their musical knowledge to the therapist. The largest attraction was to change the musical instrument easily;
- Technological Inclusion: none of patients had previous contact with an augmented reality environment.

Some negative points considered:

- Ergonomics: the table used for the accomplishment of exercises needed to be adjusted in a higher position in relation to other interventions with mass and stick, and this a lot of times generated discomfort to patients. Table adjustment was necessary so that the webcam recognized markers on tabletop. The larger the distance of table to webcam, the harder was the cards' identification. This was the main problem reported by therapists when setting up equipment and getting patient's appropriate posture before beginning the exercises.
- Many simultaneous incentives: some patients were very anxious, because there was a lot of incentive (visual and auditive) simultaneously.
- Little effect for individuals with low mobility: when a patient has low mobility, exercises didn't have a lot of effect in relation to conventional treatment.

4.7 Future perspectives

As a continuity of this work, we intend to conclude tests with patients of ABDIM and starting from that, to investigate relative subjects to the appropriate use of results of evaluations for improvement of GenVirtual.
Rehabilitation treatment protocol (with GenVirtual) is being defined in other rehabilitation centers with individuals with other deficiencies for future investigations: children with cerebral palsy in music therapy section and children with other types of muscular dystrophy in occupational therapy section of Association of Attendance to Deficient Child (AACD). In these protocols we will define the number, frequency and duration of interventions and will evaluate the treatment effectiveness. This research was previously approved by São Paulo Research AACD Ethics Committee under supervision of the music therapist section.
We intended to create new scenarios so patients can get involved in other therapeutic activities, as for example, new musical games. An investigation is being made to create a collaborative environment. This way the therapist can follow activities that the patient accomplishes at home. We also intend to investigate the possibility to create mechanisms for the therapist: observation, registration and evaluation activities.

5. Final considerations

In last years there has been some software development for treatment of several motor and cognitive disorders of people with disability. Especially, virtual and augmented reality technologies present an attractive interface generating larger motivation and consequently larger acceptance and participation in therapeutic treatment.
Virtual environments can adhere to therapeutic interventions. Multidisciplinary teams need to be involved during conception of such environments. This way, it is necessary to analyze characteristics or patients' abilities considering their limitations. For this reason, this

research was accomplished by engineers together with therapy specialists of ABDIM considering patients treated in the occupational therapy section taking into account the motive conduct, cognitive characteristic, motivation aspects and individual characteristics.
Results showed that GenVirtual can help therapeutic interventions for contemplating cognitive learning, motor, psychological-social, besides stimulating musicality. Given that it is based on a conventional computational platform, the prototype is already in condition of being used in home environments. This can propitiate family involvement in complementary activities.
It is appropriate to stand out that virtual environments presented here don't substitute conventional medical therapies. These tools empower existing treatments with pertinent use already established therapeutic process and rehabilitation techniques.

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Population ageing has major consequences and implications in all areas of our daily life as well as other important aspects, such as economic growth, savings, investment and consumption, labour markets, pensions, property and care from one generation to another. Additionally, health and related care, family composition and life-style, housing and migration are also affected. Given the rapid increase in the aging of the population and the further increase that is expected in the coming years, an important problem that has to be faced is the corresponding increase in chronic illness, disabilities, and loss of functional independence endemic to the elderly (WHO 2008). For this reason, novel methods of rehabilitation and care management are urgently needed. This book covers many rehabilitation support systems and robots developed for upper limbs, lower limbs as well as visually impaired condition. Other than upper limbs, the lower limb research works are also discussed like motorized foot rest for electric powered wheelchair and standing assistance device.

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