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# Applicability of a motor rehabilitation system in stroke victims

## *Aplicabilidade de um sistema de reabilitação motora em pacientes pós-acidente vascular encefálico*

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### Abstract

**Introduction:** The recovery of stroke patients is long and boring due to the repetitive nature of the exercises used and the length of treatment. Thus, we started using virtual reality as an alternative and, because of its advantages, health professionals are adapting video games for physical therapy. However, there are some limitations, such as the fact that games are designed for entertainment and not for therapeutic purposes. **Objective**: In order to mitigate gaps in assistive devices for physical therapy, this study describes the development and applicability of a computer support system for motor rehabilitation - Ikapp - in stroke victims. **Methods**: Twenty-seven stroke patients filled out a socioeconomic questionnaire, tested Ikapp during five minutes and answered a usability and satisfaction questionnaire about handling the tool. The chi-square test was used to analyze any association between sociodemographic factors and the features of the system. **Results**: The Ikapp system can be an excellent device to assist neurological rehabilitation of stroke patients, as participants questionnaires showed that 85.2% were satisfied in regard to motivation and inclusion of Ikapp in physiotherapy and 77.8% relative to ease of interaction with the tool. **Conclusion**: The Ikapp system proved to be an easy-to-use and accessible computer support system for patients with functional limitations.

**Keywords**: Virtual Reality Exposure Therapy. Rehabilitation. User-Computer Interface. Neuronal Plasticity.

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***Resumo***

***Introdução:*** *A recuperação de indivíduos pós-Acidente Vascular Encefálico (AVE) tem se mostrado longa e monótona devido ao caráter repetitivo dos exercícios utilizados na clínica e aos anos de tratamento. Logo, tem-se utilizado a Realidade Virtual (RV) como uma alternativa e diante de suas vantagens, profissionais de saúde vêm adaptando vídeo games à fisioterapia. No entanto, existem algumas limitações, como a do fato de estes vídeo games terem sido desenvolvidos para diversão e não serem apropriados para uso terapêutico.* ***Objetivo****: Em busca de atenuar lacunas existentes em dispositivos adaptados à fisioterapia, este estudo descreve o desenvolvimento e a aplicabilidade de um sistema computacional de suporte a reabilitação motora — Ikapp — em pacientes pós-AVE.* ***Métodos****: 27 pacientes pós-AVE preencheram um questionário socioeconômico, testaram o Ikapp durante 5 min e responderam a um questionário de usabilidade e satisfação sobre o manuseio da ferramenta. Para analisar a associação de fatores sociodemográficos com funcionalidades do sistema, o teste qui quadrado (Exato de Fisher) foi utilizado.* ***Resultados****: O Ikapp pode ser uma excelente ferramenta de auxílio à reabilitação neurológica de pacientes pós-AVE, visto que seus testes evidenciaram 85,2% de satisfação no que diz respeito à motivação e inclusão no processo fisioterápico e 77,8% em relação à facilidade de interação com a ferramenta.* ***Conclusão****: O Ikapp mostrou ser um sistema computacional de fácil aplicação e acessível a pacientes com diferentes limitações funcionais.*

***Palavras-chave****: Terapia de Exposição à Realidade Virtual. Reabilitação. Interface Usuário-Computador. Plasticidade Neuronal.*

## Introduction

Strokes are the result of a failure of the blood supply to the brain that leads to loss of functional capacity (1). As one of the leading causes of deaths worldwide (2), strokes impair brain function and activities of daily living, affecting the quality of life and functional independence of individuals (3).

Hemiparesis of the upper limb is the most common sensory-motor deficit after strokes with a prevalence of 55 - 75% of patients affected within six months of the event (4). Studies show that although physiotherapy does improve arm movement, the efficacy is heterogeneous (4), as 75% of patients fail to restore limb function (3). Considering the difficult task of recuperating the function of the affected arm, the repetitive nature of exercises and the long time to recovery highlight the need to invest in technological resources that associate leisure and therapy to reduce the tiring and discouraging character of physiotherapy (5 - 7). Consequently, studies are evaluating virtual reality (VR) as an alternative to conventional therapy (8, 9).

VR can be defined as an experience that uses interactive simulations created by software and hardware to provide users the opportunity to engage in virtual environments (VE) that resemble the real world (10). By including play, fun and motivation as therapeutic agents, it is speculated that VR tools may assist recovery after strokes (6). In fact, studies report gains in the motor, sensory and cognitive fields after VR therapies (4, 9). Health professionals have been adapting popular game consoles — developed for entertainment purposes — to physiotherapy, but this limits the therapeutic approach (10). A system with interactive technology entitled 'Ikapp' was developed with the aim of mitigating gaps in devices adapted for rehabilitation. The Ikapp system aims to innovate rehabilitation providing the patient with the ludic values found in video games, and providing the physiotherapist with detailed monitoring of the progress of treatment by the automatic generation of reports (11). In addition, the system offers a real-time assessment of movement compensation and a record of the number and type of mistakes that are made during a session (12).

Considering the innovation of Ikapp, the need of studies to analyze its applicability to stroke victims it evident, as is a measure of the level of patient satisfaction on using the tool. Moreover, the influence of sociodemographic variables, such as education level and family income, on the usability of interactive systems is discussed in this study.

## Methods

### Design, location, study period and recruitment of individuals

This descriptive study was approved by the Research Ethics Committee of the Health Sciences Center of the Universidade Federal de Pernambuco (UFPE) and enrolled stroke victims from the Applied Neuroscience Laboratory (LANA) and the Hospital das Clinicas, both of the UFPE.

Forty-eight, 30- to 80-year-old volunteers of both genders with clinical diagnosis of sensorimotor sequelae of the arm resulting from ischemic or hemorrhagic strokes (> 6 months) but with active shoulder mobility (abduction/adduction) with a minimum score of 20 (individuals with little schooling – 0 - 4 years) or 24 (individuals with > 4 years of schooling) (13) in the Mini-Mental State Examination (MMSE) were selected. Individuals with cognitive impairment, moderate visual loss, severe hearing loss, epilepsy, labyrinthitis, visual hallucinations or uncontrolled high blood pressure were excluded. All volunteers signed informed consent forms.

### Experimental procedures

The sample was characterized using a socioeconomic questionnaire. Subsequently, the patients were submitted to the interaction test and replied to a usability and satisfaction questionnaire.

### Ikapp system and patient interaction

Ikapp, a computer system that assists motor rehabilitation, contains four modules: body tracking, biomechanical analysis, the game module and report generation (12). An ASUS A42F-VX498R notebook (Intel Core i5 4GB 750GB), 14" LCD television, EPSON® S12+ Powerlite 2800 Lumens projector, Microsoft® Kinect sensor and a DSC — W530 Sony® digital camera were used for the game environment. After standard verbal instructions, the patient had one minute to become familiar with the features of the tool. Subsequently, either sitting or standing (according to the patient's physical condition), abduction and adduction movements of the paretic shoulder with extension of the elbow were recorded by the camera over four minutes. Each patient performed the test just once.

The game scenario consisted of an aircraft that should be flown to moving graphic elements. Each element demands a specific action of the patient with abduction or adduction movements of the shoulder being converted into ascent or descent of the aircraft in the VE. The distribution of elements throughout the scenario is intended to encourage the patient to perform isometric and isotonic contractions, as well as improve coordination. By varying the arrangement of these elements, the therapist can define a treatment plan depending on the therapeutic objective of each patient. During the game, visual feedback is provided through warning phrases displayed when the patient uses a harmful movement.

### Evaluation tools

- Socioeconomic questionnaire and Usability and Satisfaction Questionnaire

The questionnaires used in the study were developed based on questionnaires used in patient satisfaction studies (14) and usability studies (15). The socioeconomic questionnaire (SEQ) is composed of 13 subjective questions addressing sociodemographic aspects. The usability and satisfaction questionnaire (USQ) analyzed patient satisfaction in contact with the tool using 11 questions with the responses to the first seven graded from 1 to 5 ("very little", "little", "more or less ","much" and "very much"). The responses to Items 9 and 10 were graded from 1 to 10 and Items 8 and 11 were answered descriptively.

### Think Aloud Protocol

The Think Aloud Protocol (TAP) is a simple method of evaluation in which people are asked to vocalize their thoughts and opinions while interacting with a product (16). In this evaluation, all the volunteers were filmed and later the videos were analyzed to detect limitations and system errors.

### Analysis of the results

Descriptive statistical analysis was performed on the data collected from the SEQ and from Items 9 and 10 of the USQ. Measures of central tendency and dispersion were used for quantitative variables and frequency for categorical variables. Four people were responsible for verifying and descriptively reporting the information provided by volunteers in videos.

In the analysis of the data from the USQ, the responses to Items 1 - 7 were dichotomized using the chi-square test of the SPSS software (version 18.0). For Items 1, 2 and 7, scores of 1 - 3 were equivalent to 'dissatisfied' and scores of 4 and 5 to 'satisfied'. For Items 3, 5 and 6, the scores of 1-3 were considered 'negative' and 4 and 5 'positive'. For Item 4, the scores of 1-3 were classified as 'little' and 4 and 5 as 'much'. Items 8 and 11 were analyzed descriptively.

The chi-square test (Fisher's Exact) was applied to evaluate the relationship between the results of the USQ and the socioeconomic characteristics of patients.

## Results

Of the 61 records of potential volunteers analyzed in respect to eligibility criteria, only 27 were enrolled in the study. The characteristics of the sample are shown in Table 1.

**Table 1** - Characterization of the sample

| | |
|---|---|
| Gender - n (%) | |
| *Male* | 19 (66.7) |
| *Female* | 8 (33.3) |
| Hand preference - n (%) | |
| *Right* | 26 (96.3) |
| *Left* | 1 (3.7) |
| Hemiparesis - n (%) | |
| *Right* | 12 (44.4) |
| *Left* | 15 (55.6) |
| Age, years* | 59.11 ± 1.98 |
| Number of strokes* | 1.37 ± 0.17 |
| Time after stroke - months* | 68.15 ± 19.73 |
| Mini-Mental State Examination score* | 26.37 ± 0.42 |

Note: * Values expressed as mean ± standard error of mean.

### Socioeconomic questionnaire

The SEQ data showed that 48.1% of the volunteers had little schooling and 59.3% had a family income of up to three minimum wages. As regards to access to the media, 85.2% of them had up to three televisions, 51.9% had no computer and 74.1% had no access to internet.

### Usability and Satisfaction Questionnaire

The data the USQ revealed that Items 7 (game scenery), 4 (physical effort), 3 (inclusion in treatment) and 1 (motivation) had satisfaction percentages of 100%, 92.6%, 85.2% and 85.2%, respectively. The item that had the lowest satisfaction score — 51.9% — was Item 6 (corrective feedback). The means ± standard errors of questions 9 and 10 (control of the plane through body movements and conducting exercises at home assisted by the game) were 8.29 ± 0.38 and 8.66 ± 0.42, respectively, with 51.85% of the participants giving full marks to Item 10.

An analysis of the items 8 and 11 (insertion of graphic elements and preference of performing virtual exercises or not) showed that 95% of patients would not alter the game's scenery and most would like to perform physiotherapy using virtual games.

The videos of the TAP demonstrate that the use of the tool obtained a high level of acceptance as it was easy to use and adapt to. All patients interacted satisfactorily with the game and showed enthusiasm for the VE.

There was a significant relationship between schooling and understanding the game (p-value = 0.013), where only 60% of those who studied up to primary education were satisfied with the level of understanding (Table 2). Those who had completed at least high school were found to be 100% satisfied in relation to the degree of understanding of the activity.

There was an association between schooling and perception of corrective feedback (p-value = 0.031); 66.7% of those who studied up to primary education proved to be dissatisfied with the corrective feedback of the game. Of the individuals who completed at least high school, 75% said they were satisfied about the feedback.

There was no association between the years of schooling and motivation (p-value = 0.809). However, the data showed high degrees of satisfaction for both levels of education, with 86.7% and 83.3% of those who studied up to primary education or at least high school felt motivated by the game, respectively.

**Table 2** - Degree of satisfaction associated to the level of education of individuals and understanding of the game, corrective feedback and motivation provided by the game

| | Level of education | | p-value* |
|---|---|---|---|
| | Up to elementary school | High school and above | |
| **Understanding of the game** - *n (%)* | | | 0.013 |
| *Unsatisfied* | 6 (40) | 0 (0) | |
| *Satisfied* | 9 (60) | 12 (100) | |
| **Corrective *feedback* - *n* (%)** | | | 0.031 |
| *Unsatisfied* | 10 (66.7) | 3 (25) | |
| *Satisfied* | 5 (33.3) | 9 (75) | |
| **Motivation** - *n (%)* | | | 0.809 |
| *Unsatisfied* | 2 (13.3) | 2 (16.7) | |
| *Satisfied* | 13 (86.7) | 10 (83.3) | |

Note: * Chi-square test.

An association (p-value = 0.021) was found between family income and degree of understanding of the game. Thus, 62.5% of individuals with incomes of up to three minimum wages expressed satisfaction whereas this rate was 100% among those with incomes above three minimum wages (Figure 1).

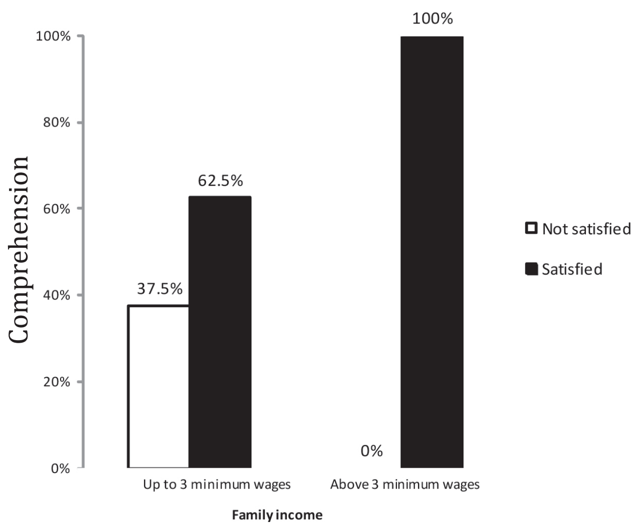


**Figure 1** - Relationship between family income and understanding of the game.

There was no correlation between prior contact with video games and the degree of motivation provided by Ikapp. Those who had previous contact with games showed a lower percentage of satisfaction (80.0%) compared to those (88.2%) who had never had any contact with video games (Figure 2). However, there were high satisfaction ratings in both groups.

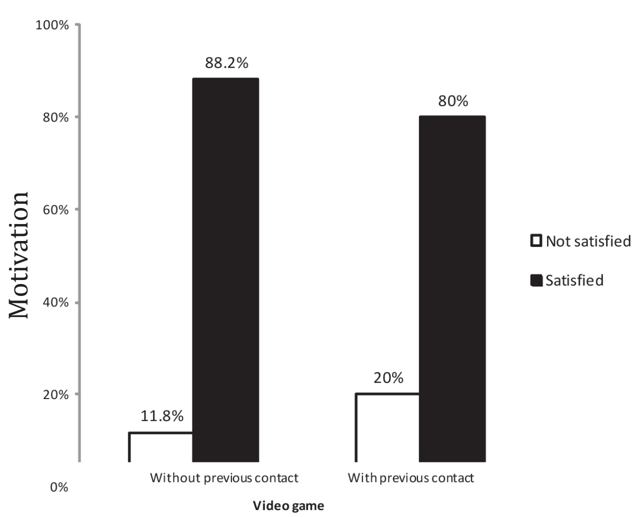


**Figure 2** - Relationship between motivation provided by Ikapp and prior contact with video games.

Again an association was found between the type of stroke and the degree of physical effort required by the game (p-value = 0.013). According to Figure 3, 100% of subjects who suffered ischemic strokes reported that the game required little effort, whereas 28.6% of those who had suffered hemorrhagic strokes reported that they needed much physical effort to play the game.

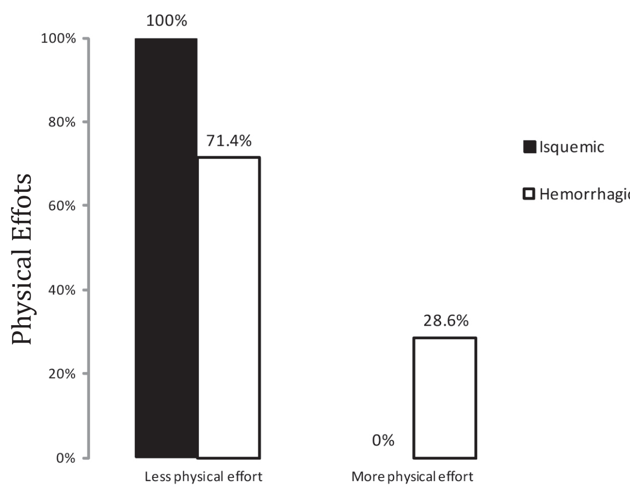


**Figure 3 -** Relationship between type of stroke and physical effort required to play the game.

No associations were found between the variables of the USQ and sociodemographic variables (p-value > 0.05).

## Discussion

The results of this study show the potential of Ikapp as a tool to assist rehabilitation after strokes, as its applicability tests showed high levels of satisfaction in relation to motivation, inclusion of the device in physical therapy and interaction with the VE.

In the opinion of the volunteers of this study, Ikapp delivers good levels of satisfaction with motivation, defined as a subjective feeling of involvement with a tool/method (17). Studies show that the user's motivation to interact with the VE is critical to the effectiveness of the application of interactive technology such as the VR in health (18). Thus, therapeutic tools that require patient engagement should be concerned mainly with this feature (19). Generally, motivation is absent in traditional rehabilitation, whose repetitive and monotonous nature of exercises is reflected in abandonment of therapy. As pointed out by Rizzo & Kim, one of the main reasons for the use of VR in rehabilitation is that the VE enhances patient involvement in treatment, and consequently adhesion to treatment. This influences motor learning, which is considered practice-dependent (20, 21), as the individual who enjoys an activity usually spends more time doing it (22).

Importantly, although interactive technologies are used for therapeutic purposes, the limitation of games adapted to physical therapy has imposed restrictions on their use. In rehabilitation, the use of the Nintendo Wii requires the user to handle joysticks during the game. This limits its use, for example, in patients with hand disabilities. In this aspect, Ikapp offers advantages as it uses an image capture technology through Kinect, wherein the tracking sensor detects body motion and translates it into an action in the VE without requiring auxiliary devices. This advantage was perceived by the patients in this study, as they expressed, during the TAP, the ease in using the tool in the face of their physical limitations.

Still on the subject of ease of interaction with Ikapp, all patients were satisfied with the game scenario. This may be another therapeutic advantage of the system which is common to other devices on the market. In rehabilitation, satisfaction with the VE is very valuable since it gives individuals an 'enriched environment' composed of diverse stimuli (auditory and visual). Research shows that motor training in this environment induces neural reorganization (plasticity) after neurological damage, impacting positively on motor rehabilitation (23).

Unlike other systems, Ikapp allows individuals to continue interacting with the game without necessarily having constant supervision of the therapist. This independence was pointed out by most patients as a positive factor and, in the context of rehabilitation, can promote the recovery of individuals. This is positive because it allows patients to continue their therapy at home without the need for direct supervision of the physiotherapist and without increasing the risk of injury. Knowing that rehabilitation after strokes is related to plastic changes occurring in the central nervous system (24), it is believed that by promoting plasticity of the injured brain, the recovery of the patient will also be indirectly promoted. Studies show that such plastic processes are practice-dependent, i.e. practice is a determining factor in the reacquisition of motor skills after neurological damage (25). Thus, it is evident that when more, specific exercises are carried out, the better and the quicker the recovery after strokes. However, in the current context, intensive practice is difficult as it requires continuous supervision of therapists.

On the advantages of Ikapp, it is important to note that the therapist can program a specific treatment plan and monitor the progress of each patient. This is possible by the arrangement of the graphic elements in the VE and from the reports containing information about the user's performance while using the system.

On creating tools such as Ikapp for use in health care, the involvement of users and how they interact with the machine should be considered, as the therapeutic process is intrinsically linked to the degree of motivation and engagement of patients (6, 7, 17). Hence, some studies have stressed the importance of testing the usability of interactive systems such as those of the VR from the perspective of users (26). However, few investigate sociodemographic variables, such as the level of education, in relation to satisfaction and the usability of technological tools.

Kang et al. developed a VE that simulates going shopping based on activities of daily living to train stroke victims (27). This study evaluated, among other factors, the level of user satisfaction with the program, the usability of the system and the influence of sociodemographic variables on the performance of patients. A relationship between the virtual performance of individuals and the level of education was highlighted as was previous experience with computers.

As demonstrated in the results of this study, there was an association between years of schooling and understanding the game and between the level of education and perception of corrective feedback. Since the average MMSE score (26.37 ± 0.42) showed that the population selected had a preserved cognitive function (13), it is suggested that such dissatisfaction rates are linked to low levels of education or because volunteers simply did not like the game and not to cognitive deficits. These findings, in part, may be related to data described in studies evaluating the influence of sociodemographic characteristics on patient satisfaction. According to Ware et al., individuals with less education tend to be less rigorous in evaluating satisfaction of medical services (28). Furthermore, dissatisfaction with corrective feedback provided by the game can also be attributed to an inadequate format. This constitutes a possible limitation of the system that can be readily adjusted since the tool is still under developed.

Regarding the results that show that 100% of individuals with family incomes above three salaries were satisfied in respect to understanding the game, Hall & Dornan reported an association between satisfaction levels and family income (29). They advocated the possibility that in higher social strata there is a greater number of individuals with high levels of education, which suggests that these individuals are also the most satisfied.

In this study, no association was found between the level of education and the motivation provided by the game (p-value = 0.809). Although the 'involvement' factor has a substantial component of subjectivity, it is directly related to the user's motivation to participate in the VE. Thus, the high percentage of satisfaction shown by Ikapp users regarding the motivation provided by the game (85.2%) is very important, as more motivated patients tend to adhere more to treatment (13).

The findings of this study indicate that sociodemographic factors, such as education and family income, influence satisfaction levels related to VE. As there are few studies about this relationship and its impact on user-machine interactions is still poorly understood, the discussion is not limited to this scientific setting.

## Conclusions

The Ikapp system proved to be an easy to apply and accessible tool for stroke victims with different levels of functional deficits that conveys the image of physical therapy as enjoyable and motivating. A biomechanical analysis of movement is a differential tool that can assist physical therapists and help patients to make exercises at home correctly and safely. It is worth noting that this study achieved its goal to test the applicability of the tool in stroke victims. However, it is suggested that more studies should be developed involving a larger number of volunteers and that in future randomized controlled trials should be conducted to confirm the therapeutic potential of Ikapp and prove that its use in physical therapy can improve the recovery of functionality of patients after strokes.

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