# Competition improves attention and motivation after stroke

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## ABSTRACT

Cognitive deficits are a common sequelae after stroke. Among them, attention impairments have the highest incidence and limit functional recovery and quality of life. Different strategies to improve attention have been presented through the years, even though its effectiveness is still unclear. Basing on the human competitive nature, competitive strategies have been proposed to increase motivation and intensity. However, this approach has been never applied to train attention after stroke. In this paper, we present a randomized controlled trial that evidences the important role of competition in cognitive functioning. Our results support that competitive strategies combining virtual reality-based and paper and pencil tasks can improve attention and motivation after stroke to a greater extent than non-competitive paper and pencil tasks.

## 1. INTRODUCTION

Cognitive impairments are among the most common sequelae after stroke, affecting to more than half of the cases (Hochstenbach et al., 1998). Among them, attention deficits present the highest incidence, with rates ranging from 46% to 92% of the cases in the acute phase (Hyndman et al., 2008). When compared to healthy controls, individuals post-stroke evidence slower reaction time and alerting deficits, which have been linked to dissociated attention networks (Rinne et al., 2013). Since attention is a basic cognitive skill that sustains higher cognitive processes, impaired attention can affect the general cognitive functioning even when other functions are intact (Lezak, 1995), thus limiting learning (Schmidt, 2011), social cognition (McDowd et al., 2003), and, in the end, functional recovery (Robertson et al., 1997) and quality of life (Nys et al., 2006). Importantly, attention deficits have been reported to be more incapacitating than motor impairments (Zhu et al., 1998).

Different interventions have been presented to improve attention after stroke (Cha et al., 2013). The customization of the rehabilitation programs, for example by adjusting both the intensity (Penner et al., 2012) and the difficulty of the tasks to each subject's condition (Brehmer et al., 2012), is essential to maximize the efficacy of the interventions. In the last decade, an increasing number of studies have reported the efficacy of computerized programs to improve different cognitive skills (Cha et al., 2013; Bogdanova et al., 2015).

Different factors have been reported to promote cognitive rehabilitation. First, audiovisual content, feedback on the performance, and cognitive challenges (Maclean et al., 2000) have been shown to increase the intensity and duration of the training while increasing the motivation (Novak et al., 2014). Second, social interaction through multiplayer strategies have been reported to improve not only motivation but also adherence to the treatment (Carignan et al., 2006). Actually, users have reported to prefer multiplayer to single-user interaction via either competitive or non-competitive exercises (Wittchen et al., 2013). However, there is no previous reports on the effects of competitive training on attention rehabilitation.

The objective of this study is threefold. First, to determine the efficacy of a competitive group intervention to improve attention deficits in chronic stroke survivors in comparison to a non-competitive group program. Second, to evaluate the motivation elicited by both interventions. Finally, to determine the usability of a virtual reality-based multiplayer competitive system used in the competitive intervention.

# 2. METHODS

## *2.1 Participants*

Participants were recruited from the stroke outpatient management program of NISA Valencia al Mar Hospital (Valencia, Spain). The inclusion criteria for the current study were: 1) chronicity > six months; 2) slow processing speed, as defined by T-scores of the reaction time in the Conners' Continuous Performance Test 2nd Edition (CPT) (Homack et al., 2006) ≥ 60; 3) fairly good cognitive condition, as defined by scores on the Mini-Mental State Examination (Folstein et al., 1975) > 23; 4) inclusion in a cognitive rehabilitation program for more than 3 months. Participants were excluded if they had: 1) impaired comprehension that hindered sufficient understanding of the instructions, as defined by Mississippi Aphasia Screening Test (Romero et al., 2012) scores below 45; 2) severe visual impairments; 3) severe paresis of the upper limb that prevent interaction with the instrumentation, as defined by Upper Extremity subscale of the Fugl-Meyer Assessment (Sanford et al., 1993) < 19; 4) spatial neglect; and 5) emotional or behavioural circumstances that impeded adequate collaboration.

The study was approved by the Institutional Review Board of the NISA Valencia al Mar Hospital. All the subjects who satisfied the inclusion criteria and accepted to participate in the study provided written consent.

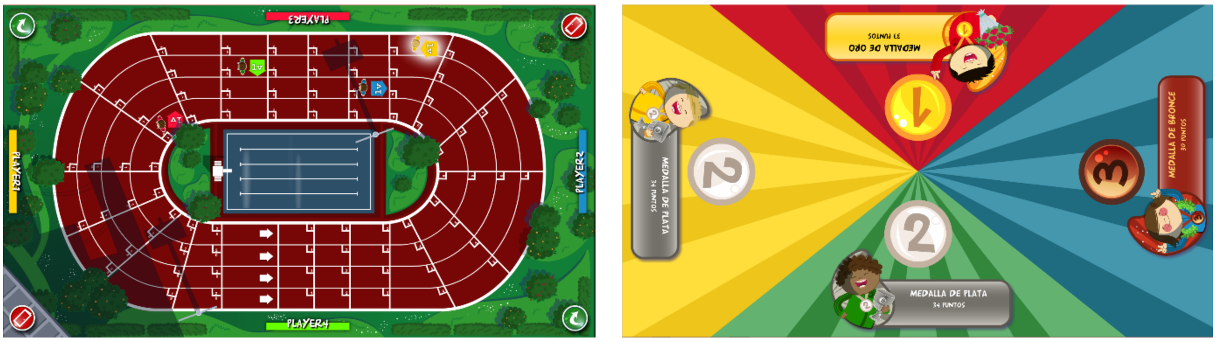
Participants were randomly assigned to an experimental or a control group. The allocation sequence was concealed from an independent researcher. A sealed envelope identifying the group of each participant was given to the therapists to inform them of the allocation. Randomization was computer-generated using a basic random number generator in a ratio of 1:1.

## *2.2 Instrumentation*

*2.2.1 Paper and pencil tasks.* A battery of conventional paper and pencil tasks was designed to train different attentional skills. Exercises focused on alertness, reaction time, selective, divided, and sustained attention, while involving visual scanning, visual memory, and working memory. The results of the exercises provided information about correct and wrong answers, and reaction time.

*2.2.2 Multiplayer virtual reality-based system.* A multitouch table system with customized exercises was used during the intervention. The system consisted of a conventional 42″ LCD screen embedded in a conventional table and oriented in a horizontal plane (parallel to the floor) (Llorens et al., 2012; Llorens et al., 2013). The interactive capability was provided by a multitouch frame fixed over and along the screen frame that detected a maximum of 32 touches simultaneously. The system allowed different participants to sit in each side thus enabling group-based interventions with high reports of motivation and usability (Llorens et al., 2015). The system run on an Intel® Core™2 E7400 @2.8GHz with 3 GB of RAM and a NVIDIA® GeForce® 9800 GT video card with Windows 7. Visual and auditory feedback was provided using the TV speakers.

The multi-touch screen displayed the virtual environments, which were inspired in the Olympic Games. The main screen of the game displayed a running track from above with different avatars that represented the participants (Figure 1.a). Different races and male and female characters were available.




*(a)* *(b)*

**Figure 1.** *Snapshots of: a) the main screen; and b) the results screen after each exercise.*

The main objective of the game, as in track and field, was to move further away than the rest of the participants. To this end, participants had to compete in different exercises. Participants moved forward in the track according to their performance in the exercises. Specifically, the winner moved forward 4 steps, the runner-up moved forward 3 steps, and so on (Figure 1.b). In case of draw, the participants achieved the same score and consequently moved the same numbers of steps.

The system included eight exercises that focused on the same attentional skills that were involved in the paper and pencil tasks, mainly related to attention, and recreated different Olympic events and scenarios (Table 1, appended). Besides the cognitive demand of each exercise, the timing of the required actions was important. As a proof, in marathon and public, participants had to grab an item or to identify a character as fast as possible, respectively. In contrast, all the actions in cycling, tennis, duathlon, and triathlon had to be done at the precise moment, which was highlighted in the environment with changing colors (for instance, in cycling, when an obstacle entered in the area of interaction of the character, the area turned into green, thus indicating that the user should press the button to avoid the obstacles). This way, not only reaction was trained but also impulsiveness.


**Figure 2.** *Snapshots of the exercises: a) marathon; b) cycling; c) tennis; d) public; e) football; f) soccer; g) duathlon; and h) triathlon.*

Participants interacted with the game board by touching buttons or other items on the screen (Table 1). The level of difficulty was customizable by adjusting different parameters in each exercise (Table 1). During the exercises, the system provided feedback about the number of right and wrong answers, the remaining time, and the current position. At the end of them, a small closing ceremony with the medal awards was recreated to provide general feedback of the performance.

### *2.3 Procedure*

All the participants underwent 30 one-hour group sessions of four participants administered 3 days a week. Number of sessions and dosage were, consequently, paired. Interventions, in contrast, differed between groups. Participants belonging to the control group trained using the battery of paper and pencil tasks described above. Participants belonging to the experimental group trained using competitive exercises, alternating sessions of paper and pencil tasks with sessions using the described multiplayer virtual reality-based system. In the control group, paper and pencil tasks were completed in group but independently. In the experimental group, the same tasks were completed competing to finish in first place, with the highest number of right answers, or with the lowest number of errors. Sessions with both paper and pencil tasks and the multiplayer system included 8 exercises that focused on the cognitive skills described previously in randomized order. The duration of each exercise, either paper and pencil or through the virtual reality-based system, was 6 minutes. Breaks of 1.5 minutes were allowed between them. All the sessions were conducted by an experienced therapist who gave feedback about the results after each exercise and specific instructions before each exercise (during the breaks). The difficulty of all the exercises was determined in an exploratory session according to participants' condition.

Participants were assessed before and after the intervention with a battery of clinical tests that evaluated visual scanning, reaction time, sustained attention, and inhibition, abilities that were mainly trained during the intervention. The assessment included the CPT, the d2 attention test (d2) (Bates et al., 2004), and the Part A of the Trail Making Test (TMT-A) (Reitan, 1958). The CPT is a computerized test that assesses multiple facets of attention, as reaction time, selective and sustained attention, and impulsivity. In the second edition of the test, clients are told to click the space bar as quick as possible when they are presented with any letter except the letter "X". Stimuli are presented at 1, 2, or 4 s intervals, thus defining different blocks, during 14 minutes. The d2 is a paper and pencil test that assesses visual scanning speed and selective and sustained attention. The test has 14 lines with series of similar letters surrounded by marks. Participants are required to cross out any letter "d" with two marks around above it or below it that are present in each line and discard distractors. Participants have 20 s to finish each line. The TMT-A is a paper and pencil task that evaluates visual search speed and scanning. The test consist of 25 numbered circles distributed over a sheet of paper. Participants are required to draw lines to connect the numbers in ascending order as quickly as possible.

Reaction time was assessed with the Hit Reaction Time score of the CPT (CPT-HitRT), the average speed of correct responses for the entire test, and the time to complete the part A of the TMT (TMT-A). Sustained attention was assessed with the total score of the d2 (d2-T), the Hit Reaction Time by Block (CPT-HitRT-BC), which measures change in reaction time across the duration of the test, and the Standard Error by Block (CPT-HitSE-BC), which detects changes in response consistency over the test. Inhibition was assessed by the Commisions score of the CPT (CPT-COM), i.e. the responses given to non-targets, and the Concentration Index of the d2 (d2-CON), which is the difference between number of right answers and commisions.

In addition to the clinical assessment, after the intervention, participants reported their motivation through four subscales of the Intrinsic Motivation Inventory (IMI) (McAuley et al., 1989). Participants belonging to the experimental group also assessed the usability of the system with the System Usability Scale (SUS) (Bullinger et al., 1991). The IMI is a multidimensional questionnaire structured into various subscales. Each subscale includes different questions rated on a seven-point Likert scale. In this study, this questionnaire was used to assess participant interest/enjoyment, perceived competence, pressure/tension, and value/usefulness measures. The SUS is a simple ten-item scale that serves as a global assessment of subjective usability. It employs a Likert scale with scores ranging from 0 to 100.

### *2.4 Data analysis*

Demographical and clinical comparisons between the control and the experimental group were performed with independent sample t-tests and Chi-squared or Fisher exact tests, as appropriate. Repeated measures analyses of variance (ANOVA) with time as the within-subjects factor and treatment option (control versus experimental) as the between-subjects factor were performed for the clinical tests and the motivation quesionnaire. The main effects were evaluated for time, treatment option, and the time-treatment option interaction. ANOVA findings that violated the sphericity assumption were accommodated by Greenhouse and Geisser's conservative degrees of freedom adjustment. For each repeated-measures ANOVA, we present the partial eta squared ($\eta^2 p$) as a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measure of effect size; values may range between 0 and 1, with higher values representing higher proportions of variance explained by the independent variable.

The α level was set at 0.05 for all analyses (two-sided). All analyses were computed with SPSS Statistics version 22 (IBM®, Armonk, NY, USA). Investigators performing the data analysis were blinded.

## 3. RESULTS

### *3.1 Participants*

A total pool of 106 subjects were eligible candidates to participate in this study. Of those, 27 subjects (25.5%) met inclusion criteria. None of them refused to participate in the study, and consequently all of them were randomized. The experimental group consisted of 14 participants and the control group consisted of 13 participants. Two participants, one of each group, discontinued during the intervention due to discharge and worsening health. Consequently, these data were not considered for analysis. Data from 25 participants, 13 in the control group and 12 in the experimental group, were included in this study. The final sample consisted of 15 males and 10 females, with a mean age of 54.4±9.0 years, and a mean chronicity of 402.8±295.5 days. A total of 15 participants presented an ischemic stroke, and 10 participants presented a hemorrhagic stroke (Table 2). No significant differences in demographical (gender, age, and education) or clinical (etiology, localization, chronicity, and CPT-HitRT) data at inclusion were detected between the groups.

**Table 2.** *Characteristics of the participants. Data are expressed in mean ± standard deviation when possible.*

| Characteristic | Control group | Experimental group | Significance |
|---|---|---|---|
| *Sex (n,%)* | | | |
| *Male* | 9 (69.2 %) | 6 (50.0 %) | NS (p=0.327) |
| *Female* | 4 (30.8 %) | 6 (50.0 %) | |
| *Age (years)* | 54.3±8.8 | 54.5±9.6 | NS (p=0.971) |
| *Education* | 13.6±4.3 | 11.2±3.7 | NS (p=0.139) |
| *Chronicity (days)* | 289.2±98.4 | 266.4±78.4 | NS (p=0.530) |
| *Etiology (n,%)* | | | |
| *Hemorrhagic* | 4 (30.8 %) | 6 (50.0 %) | NS (p=0.327) |
| *Ischemic* | 9 (69.2 %) | 6 (50.0 %) | |
| *Localization (n,%)* | | | |
| *Right* | 6 (46.1%) | 1 (8.3 %) | NS (p=0.202) |
| *Left* | 5 (38.5%) | 6 (50.0 %) | |
| *Bilateral* | 0 | 2 (16.7 %) | |
| *Cerebellar* | 1 (7.7 %) | 2 (16.7 %) | |
| *Brainstem* | 1 (7.7 %) | 1 (8.3 %) | |
| *CPT Hit reaction time (s)* | 471.9±99.4 | 488.7±131.3 | NS (p=0.721) |

### *3.2 Clinical measures*

The analysis of the results revealed that both groups improved their reaction time, sustained attention, and inhibition (not in the CPT-COM) after the intervention (Table 3). With respect to the clinical measures throughout the therapy, post hoc analysis showed that participants improved in all the measures but in the CPT-HitRT-BC and the CPT-COM. When comparing the progression of both groups, participants belonging to the experimental group significantly improved in the CPT-HitRT and the TMT-A, both measuring reaction time, and in both indexes of the d2. The only worsening after the intervention was experienced by the experimental group in the CPT-COM.

### *3.3 Motivation and usability*

Participants in the experimental group reported the competitive training to be significantly more enjoyable and useful than the non-competitive training, and reported that the multiplayer system used in the experimental intervention had high acceptance in terms of usability (Table 4).

**Table 3.** *Clinical data. Data are expressed in mean ± standard deviation when possible. T: time effect. GxT: group-by-time effect. NS: no significance. *: p<0.05. **: p<0.01.*

| Measure | Initial assessment | Final assessment | Significance (p, effect size) |
|---|---|---|---|
| **Reaction time** | | | |
| *CPT Hit Reaction Time (ms)* | | | T* (p=0.019, $\eta^2$=0.22)<br>GxT* (p=0.045, $\eta^2$=0.16) |
| Control | 471.9±99.4 | 466.5±79.7 | |
| Experimental | 488.7±131.3 | 426.0±104.7 | |
| *Trail Making Test. Part A (s)* | | | T** (p=0.004, $\eta^2$=0.31)<br>GxT* (p=0.014, $\eta^2$=0.24) |
| Control | 60.8±21.6 | 58.5±22.0 | |
| Experimental | 68.2±26.0 | 44.5±18.5 | |
| **Sustained attention** | | | |
| *d2 Total score (n)* | | | T* (p=0.015, $\eta^2$=0.23)<br>GxT* (p=0.018, $\eta^2$=0.22) |
| Control | 289.8±72.2 | 291.9±57.1 | |
| Experimental | 249.0±112.9 | 386.1±178.8 | |
| *CPT Hit Reaction Time by Block (ms)* | | | |
| Control | 7.7±20.5 | 0.8±22.2 | T** (p=0.003, $\eta^2$=0.32) |
| Experimental | 24.2±17.3 | 13.3±10.7 | |
| *CPT Standard Error by Block (ms)* | | | |
| Control | 45.4±64.6 | 39.2±34.5 | NS |
| Experimental | 19.2±34.2 | 10.8±41.7 | |
| **Inhibition** | | | |
| *d2 Concentration Index (n)* | | | T* (p=0.019, $\eta^2$=0.28)<br>GxT* (p=0.045, $\eta^2$=0.27) |
| Control | 105.8±36.5 | 106.5±24.4 | |
| Experimental | 73.1±56.0 | 151.0±93.3 | |
| *CPT Commisions (n)* | | | |
| Control | 10.0±5.2 | 9.8±5.5 | NS |
| Experimental | 9.0±7.8 | 12.2±5.9 | |

**Table 4.** *Motivation, enjoyment, and usability data. Data are expressed in mean ± standard deviation when possible. NS: no significance.*:p<0.05. **:p<0.01.*

| Measure | Control group | Experimental group | Significance |
|---|---|---|---|
| *Intrinsic Motivation Inventory* | | | |
| *Interest/enjoyment* | 5.2±1.0 | 6.1±0.8 | p=0.030 |
| *Perceived competence* | 4.8±1.1 | 4.9±1.5 | NS (p=0.873) |
| *Pressure/tension* | 2.1±1.0 | 3.0±1.7 | NS (p=0.111) |
| *Value/usefulness* | 5.2±1.2 | 6.1±0.8 | p=0.037 |
| *System Usability Scale* | - | 81.3±10.9 | - |

## 4. CONCLUSIONS

Although some previous studies have focused on restoring the attentional functions after stroke, none of them have used a competitive strategy (Cha et al., 2013). This study evaluates the efficacy of a competitive rehabilitation program to improve attention deficits after stroke in comparison to conventional non-competitive paper and pencil tasks. Our findings support the efficacy of both rehabilitation programs. Both, control and experimental interventions promoted significant benefits after treatment with regards to reaction time (CPT-HitRT, TMT-A), sustained attention (d2-T, CPT-HitRT-BC), and inhibition (d2-CON).

In addition, participants belonging to the experimental group showed greater benefits than healthy subjects in almost all these measures. Only one of the measures of sustained attention (CPT-HitRT-BC) did not show a group-by-time interaction, but even in this case, the competitive strategy provided higher improvement than the non-competitive training. The intrinsic motivation derived from the competitive approach could have led to a self-promoted more intensive intervention. Previous studies have consistently shown that virtual reality may be able to increase patient motivation during motor rehabilitation (Popovic et al., 2014). In addition, competition, when played in a controlled environment, may act as an extrinsic incentive to reinforce learning (Deci et al., 1999). It has been suggested that cognitive training of certain attentional domains might be more effective than others (Cappa et al., 2005), as is the case of divided attention (Cha et al., 2013). Interestingly, the use of computerized systems to improve attention has described benefits in a wider spectrum of attentional measures, specifically in processing speed, which supports our results, and in working memory (Bogdanova et al., 2015). However, previous reports comparing conventional and computerized intervention in attention programs are not conclusive (Barker-Collo et al., 2009; Bogdanova et al., 2015), and some authors argue that there is limited evidence of improvement in performance of specific attention tasks after computerized programs (Teasell et al., 2014). This could support that the improvement described in the experimental group is promoted by the competitive approach, beyond the multiplayer system.

The worsening in the inhibition described by the CPT-COM could be an effect of the improvement in the alertness and reaction time experienced along the intervention. This way, while participants could react before, it could have also led them to be more impulsive and increase the commissions.

With regards to the motivation, even though participants who competed experienced non-significant but higher levels of tension, this group assessed this intervention as being more enjoyable and useful than non-competitive training. In addition, participants who used the multiplayer system rated it as being highly usable, with scores clearly above the suggested cut-off of 70 that classifies systems as acceptable.

These results must be interpreted taken into account the limitations of the study. First, the sample size, even though it is similar to or even greater than that in other studies, can be considered small. Second, data of personal traits were not available, thus preventing the analysis of their implication in effectiveness and motivation of the training. Third, since participants were attending a rehabilitation program for three months, it is not possible to discern whether the improvement detected in both groups was promoted by the intervention or by the change of intervention itself. Finally, follow-up data, which could have depicted the maintenance of gains, is not available. Future studies should address these issues. However, the chronicity of the sample and the results evidence the positive effects of competitive strategies to train attention after stroke.

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**Table 1.** *Description of the competitive exercises of the multiplayer system.*

| Exercise | Skill | Environment | Interaction | Objective | Input parameters | Output parameters |
|---|---|---|---|---|---|---|
| *Marathon* | Sustained attention | A road with a running character. Different items appear above him/her (Figure 1.a) | One button: To grab | To grab water and fruits as fast as possible and avoid the brick | Speed | Correct answers, Omissions, Commissions |
| *Cycling* | Alertness and selective attention | A road with a cycling character. Different obstacles approach (Figure 1.b) | Two buttons: To turn To brake | To avoid puddles and logs in the road or stop at level crossing | Speed, Area of interaction | Correct answers, Omissions, Commissions |
| *Tennis* | Impulsiveness | A doubles game in a tennis court (Figure 1.c) | Two buttons: Left player Right player | To return the ball with the left or right player | Speed, Area of interaction, Time between ball shots | Correct answers, Omissions, Commissions |
| *Public* | Visual scanning | A grandstand full of fans (Figure 1.d) | Screen touches | To identify facial features in the crowd as fast as possible | Time to identify the features, Number of characters, Number of features | Correct answers, Omissions, Commissions |
| *Football* | Visual tracking | A football field with players of two teams (Figure 1.e) | Screen touches | To identify football players and a ball after a play | Number of players, Number of players to be tracked, Duration of the play, Time to decide, Presence of distractor | Correct answers, Omissions, Commissions |
| *Soccer* | Visual memory and working memory | A soccer field with players of two teams (Figure 1.f) | Screen touches | To connect dots repeating a sequence forwards or backwards | Time to decide, Number of sequences to increase the length | Correct answers, wrong answers |
| *Duathlon* | Divided attention | Split screen with marathon and cycling environments (Figure 1.g) | Two buttons: Todasdas grab To turn | To grab water and fruits while avoiding puddles and logs | Marathon: Lifetime of the items Cycling: Speed, Area of interaction | Correct answers, wrong answers of each event |
| *Triathlon* | Divided attention | Split screen with marathon and cycling environments and a pool with a swimmer (Figure 1.h) | Three buttons: To grab To flip To turn | To grab water and fruits while avoiding puddles and logs and flip turn | Marathon: Lifetime of the items Cycling: Speed, Area of interaction Swimming: Speed, Area of interaction | Correct answers, wrong answers of each event |