Rehabilitation of the upper arm early after stroke: Video games versus conventional rehabilitation. A randomized controlled trial

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Abstract

Background. Few rehabilitation methods have proven their efficacy in increasing sensori-motor recovery and/or function of the upper limb (UL) after stroke. Video games (VGs) are promising tools in this indication.

Objective. To compare UL rehabilitation by using VGs and conventional rehabilitation (CR) in patients with sub-acute stroke.

Design. Single-blind, multicentric trial, with central randomization and stratification by center.

Setting. Physical and rehabilitation medicine departments of 2 university hospitals.

Participants. Adults within 3 months after a first vascular cerebral accident, with UL Fugl Meyer Score (UL-FMS) <30/66 and without major cognitive impairment.

Intervention. A 45-min additional session of conventional occupational therapy (OT) or a VG-based OT session as add-on therapy to usual rehabilitation programs, 5 days/week for 6 weeks.

Main Outcome Measures. Primary outcome: UL-FMS. Secondary outcome: Box and Block Test (BBT), Wolf Motor Function test (WMFT), Motor Activity Log (MAL), Barthel Index and quality of life (SF-36).

Results. We included 51 patients (20 women) at a mean (SD) of 27.2 (19.4) days post-stroke (mean age 58 years [range 24-83]), 26 in the CR group and 25 in the VG group (23 in each group at 6-month follow-up). The mean duration of the additional rehabilitation session was similar in both groups: 29.3 (4.3) vs 28.0 (4.4) min in CR and VG groups. Shoulder pain occurred in 4 patients in the VG group versus 7 in the CR group. At day 45, gain in UL-FMS did not significantly differ between the groups (CR mean 17.8 [14.6] vs VG 24.1 [14.8]; p=0.10), whereas gain in BBT was doubled in the VG group (CR 7.4 [12.2] vs VG 15.7 [16.3]; p=0.02). At 6-month follow-up, the study was inconclusive about between-group differences in UL-FMS, BBT and other criteria. Post-hoc analysis showed that gains in UL-FMS or BBT were significantly higher in the VG than CR group for patients included within 30 days post-stroke.

Conclusion. In general, we cannot conclude that video gaming and conventional OT led to different long-term sensorimotor recovery of the UL after sub-acute stroke. However, when applied within the first month after stroke, video gaming was more efficient than conventional rehabilitation on both sensorimotor recovery and gross grasping function.

Trial registration. ClinicalTrials.gov (NCT01554449)

Key Words. stroke; upper limb; video games; rehabilitation

Introduction

More than 75% of stroke patients have remaining upper-limb (UL) impairment at the chronic stage (1), which renders the rehabilitation of the UL after stroke challenging. We suspect that UL rehabilitation must be intensive, repetitive and task-oriented (2). Despite an increasing interest during the past 2 decades, few rehabilitation methods have proven their efficacy in increasing sensori-motor recovery and/or function of the UL after stroke (3).

Video games (VGs) are promising tools in this indication. However, rehabilitative VGs include different kind of devices, so comparison between studies is difficult. The first studies were mainly based on the use of “commercially available VGs”, whereas more recently, "specifically designed VGs" for the rehabilitation of stroke patients have been developed and tested. Subsequently, non-immersive games and immersive ones (virtual reality) have been tested, despite different potential efficacy (4). The technical devices supporting the games widely varied in the literature, from historical dedicated consoles such as Nintendo (Wii©), Sony (Playstation©) or Microsoft (Xbox©), to personal computers, numeric tablets or customized stations. The playing interface also widely varied among surveys: mouse or joystick, graphic tablet, optic motion capture sensors such as Kinect©, mechanical support such as Armeo©, or motorized interface such as InMotion Robot or Reaplan© bridging the gap with rehabilitation robotics.

The rationale of UL rehabilitation with VGs first relies on the opportunity to increase repetition, duration, and intensity of exercises (5). VGs offer goal-oriented tasks and repetitive exercises in an enriched and interactive environment, highly suspected to increase recovery after neurological lesion. As compared with "commercially available VGs", "specifically-designed VGs" enable therapists to adapt gameplay and game design (6)(7) as well as modulate the sensory feedback provided to the patient to enhance learning, through the manipulation of visual, auditory, haptic/sensitive feedback (8) (9). Whatever their technical specificities, VGs are known to increase motivation and engagement of patients in their rehabilitation program, thereby encouraging a higher number of repetitions and longer periods of training (10). Specific effects of VG rehabilitation on neuroplasticity have been poorly investigated and are still debated (11).

When we started the study in 2010, the literature was promising although inconclusive about the efficacy of VGs when applied to sensorimotor rehabilitation of the UL after stroke. The promising results from initial studies (12) (3) (4) (12) unfortunately relied on a large amount of open-labelled and uncontrolled trials, reporting results of short trials on a small sample of patients, mostly in the chronic phase after stroke. Finally, if VGs were suspected to have some minor effects on body structure/function and activity, all authors agreed on the lack of a demonstrated effect on participation outcomes or quality of life.

From these studies, we decided to conduct a randomised controlled trial (RCT) comparing VG-based occupational therapy (OT) and the same amount of conventional OT based on 4 hypotheses:

- Main hypothesis: VG-based OT is more efficient for UL impairment and function rehabilitation in patients with sub-acute stroke because VG more easily provides high-intensity and repetitive task-specific practice.
- Secondary hypotheses:
    - VG-based OT is more efficient than conventional OT in terms of general function and quality of life.
    - VG-based OT is safe and feasible.
    - VG-based OT is more efficient than conventional OT when applied early after stroke because the increased activity due to VGs aligns with the critical window for neurological repair.

Methods

This study was a multicentric single-blind RCT. It was approved by the regional ethics committee (IDRCB: 2010-A00596-33) and was registered in ClinicalTrials.gov (NCT01554449). All patients gave their written informed consent before enrollment and procedures conformed with the Declaration of Helsinki.

Participants

Patients were recruited from physical and rehabilitation medicine departments of 2 university hospitals between January 2011 and June 2016. Inclusion criteria were age > 18 years, first ischemic or hemorrhagic stroke, time since stroke < 3 months, and UL Fugl Meyer Score (UL-FMS) <30/66. Non-inclusion criteria were visual troubles limiting computer use, cognitive impairment with Mini Mental Scale score < 22 (13), hemispatial neglect with Catherine Bergego Scale score $> 14/20$ (14), aphasia with Boston Aphasia Quotient $< 4/5$ (15), and patient's or legal representative's refusal to participate in the study. A total of 51 patients with stroke were included in this trial, plus 12 healthy controls from a functional MRI analysis that was previously published (16).

Study design

The study was a single-blind RCT. Patients were randomly assigned at a 1:1 ratio to receive 30/45 min of additional conventional OT rehabilitation (CR) or non-immersive video gaming rehabilitation (VG) under OT supervision. The randomization sequence was centralized (online using Ennov Clinical software) and computed in permuted blocks by the statistician who used SAS (SAS Institute, Cary, NC) with stratification by center.

Rehabilitation program

All patients underwent the same CR protocol, whose content was harmonized between the 2 participating centers (see Table 2). This protocol included 2 sessions/day of 30 min each of physiotherapy focusing on passive and active mobilization of the limbs, balance exercises, muscular strengthening, and walking. It also included a 30- to 60-min OT session to improve the patient's autonomy in activities of daily living, including prehension and grasping exercises. Patients with swallowing and/or language disorders received up to 2 additional sessions of speech therapy. The total duration of this "baseline" rehabilitation program ranged from 90 to 180 min/day depending on patient's needs.

All patients received an additional session of rehabilitation under the close supervision of an occupational therapist, 5 days/week, for 6 consecutive weeks. The duration of this additional session was adapted depending on the patient's weakness and tolerance: at least 15 min/day (usually at the onset of the rehabilitation period), at most 45 min/day.

- In the CR group, patients received conventional OT focusing on intensive, repetitive, and task-oriented movements of the affected UL. When patients presented grasping capacities, various prehension exercises were added. Therapists were not allowed to use VGs, electromechanical or robotic devices in this group.
- In the VG group, patients received OT based on video games played with the affected UL. During the first half of the session, patients played VGs that were configurable by the therapist in terms of speed, difficulty, distance and size of the targets, design of the scenes, number of distracters, and visualization of the scoring of the performance. One game automatically adapted target distance depending on the patients' reaching zone (7) and was used at least 10 min/day. During the second half of the session, patients played online games that were previously selected by a group of therapists with the following criteria: slow and easy-to-play, as few as possible distracters, requiring repetitive movements of the mouse, and low cognitive demand. These 30 games were grouped on a dedicated server that was the same at both experimental sites. The objective was to provide a large number of games to vary the content of the sessions and to adapt the games to each patient's motor and cognitive impairment.

Outcomes

Patients were assessed before the beginning of the rehabilitation protocol (V0) and at the end of the program, between days 45 and 60 (V1). They had a follow-up assessment at 6 months (V2) after inclusion. At each visit, the same trained physician conducted a detailed clinical examination and the tests described below. This physician was blinded to the randomization group of the patient and was not involved in administering study interventions. Adverse events were collected throughout the study.

The UL Fugl Meyer Score (UL-FMS, maximal score 66) was used as a primary endpoint to assess UL sensorimotor impairment (17). In the sub-acute stroke stage, a difference of 9/10 points on the UL-FMS is considered a Minimal Clinically Significant Difference (18).

The Box and Block Test (BBT) was used to assess overall gross grasping capacities (19). The BBT consists in grasping, moving and releasing a maximum number of 2.5-cm wooden cubes from one box to another in 1 min. Healthy persons move from 65 to 75 blocks/min, depending on the age. The Minimal Clinically Significant Difference of the BBT in patients with sub-acute stroke is unknown (20), but its Minimally Detectable Change is known to be 5.5 blocks/min (19).

We used the Wolf Motor Function Test (WMFT) to measure motor function of the UL (20) and the Motor Activity Log (MAL) to estimate perceived upper-extremity participation restrictions (21). Quality of life was assessed by the Medical Outcomes Study Short Form 36 (SF-36) (22) and independence for activities in daily living by the Barthel Index on a 100-point score (23).

Statistics

Sample size estimation

According to the team's ongoing work at the time of the protocol development, we expected a difference of gain in UL-FMS total score of 10 points ± 10 between the 2 groups. With a 2-sided α error of 0.05 and a β error of 0.10, the sample size was estimated at 22 patients per group. Considering a dropout rate of about 8%, we needed to include a total of 50 patients.

Statistical analysis

Categorical variables are expressed as number (%) and quantitative variables as mean (SD) or median [Q1-Q3]. Shapiro-Wilk's test was used to test the normality of continuous variables. The primary outcome was the gain in total UL-FMS at V1 from baseline (V1-V0). Secondary outcomes were gains at V1 or V2 (V2-V0) in distal or proximal UL-FMS, BBT score of the affected hand, WMFT, MAL, Barthel Index and SF-36. In the main analysis, differences in gains at V1 and V2 between the 2 groups were analyzed by Student *t* test or Wilcoxon test, according to the normality of data distribution. Analyses were computed on an intention-to-treat basis.

Linear mixed models for repeated measures were performed to analyze the association between intervention group and evolution in UL-FMS and BBT score of the affected hand over the 6-month follow-up. Because the post-stroke delay was strongly associated with the variation of scores and cerebral plasticity is highest during the first month after stroke (24), models were performed in the 2 sub-groups classified by the post-stroke delay (time to first protocol session ≤ 30 and > 30 days). Time, Group (video game vs control) and Group x Time interactions (to test the differences in changes over time between groups) were modeled as fixed effects with the test scores as dependent variables. Participants were considered a random effect.

$P<0.05$ was considered statistically significant. The statistical analysis was performed at the epidemiology and clinical research unit of Montpellier University Hospital with SAS Enterprise Guide v7.13 (SAS Institute, Cary, NC).

Results

Recruitment of patients lasted from October 2012 to February 2016 after reaching the number of subjects to treat, and the study follow-up ended in August 2016. The total study sample was 51, with 25 patients in the VG group and 26 controls (Fig. 1). All participants completed the program and the first assessment (week 6, primary outcome). At the second assessment (month 6), 46 patients were evaluated, 23 in each group.

Mean age of the sample was 58 years; 61% were male. Baseline characteristics were comparable between groups (Table 1). Upon inclusion in the study, the median [Q1–Q3] time since stroke was 21 [12-36] days, with 61% of the sample included before 30 days. The number and duration of therapy sessions were similar in both groups (Table 2).

The primary outcome, gain in total UL-FMS at week 6, did not significantly differ between the 2 groups (Fig. 2): 17.8 (14.6) versus 24.1 (14.8) for control and VG groups ($p=0.10$). Gains at week 6 were significantly higher in the VG than control group for distal UL-FMS ($p=0.02$) and BBT ($p=0.02$) but not proximal UL-FMS, MAL items, WMFT, SF-36, or Barthel Index (Table 3, left columns). At 6 months, BBT showed higher gains in the VG than control group but not significantly ($p=0.055$); other results were not significantly different between the 2 groups (Table 3, right columns).

In post-hoc multivariate analyses, we found a significant increase in total UL-FMS over time ($p<0.0001$), comparable in both groups, and strongly explained by post-stroke delay ($p=0.009$). As a consequence, we ran separate analyses as a function of time since stroke with a threshold at 30 days. If VG-based OT rehabilitation started within 30 days after stroke, VG therapy was more efficient for total UL-FMS (Time x Intervention interaction, $p=0.02$), but not if rehabilitation started after 30 days ($p=0.85$). Similar results were found for distal UL-FMS and BBT scores (Fig. 3).

Eight participants exhibited adverse events related to the study: 5 in the control group and 3 in the VG group. These events included shoulder pain (6), complex regional pain syndrome (1), and worsening of spasticity (1).

Discussion

Our study shows that non-immersive VG-based rehabilitation of the UL is not superior to a same amount of conventional OT in patients with subacute stroke, when considering UL sensori-motor impairment (UL-FMS), UL function (BBT and WMFT), activities of daily living (Barthel Index) and quality of life (SF-36). These results are consistent with the recent literature in the field.

Some early studies conducted in the 2000s and reviewed by Saposnik and Levin (25) suggested a weak positive effect of VG-based rehabilitation as compared with conventional rehabilitation programs. Despite encouraging recent reviews partially confirming these positive results (26)(27), the evidence of efficiency is very low, and no conclusions can be drawn from most of these trials because of methodological weakness or very low samples.

Over the last 5 years, an increasing number of negative RCTs have been published that also temper the initial enthusiasm. These studies failed to demonstrate the positive effect of VG on impairment and function, especially when they compared the same dose of rehabilitation with conventional methods. Choi et al. (28) published a small but convincing negative RCT of 20 subacute stroke patients, comparing Nintendo Wii® rehabilitation and the same duration of conventional rehabilitation. Prange et al. (29) compared the effect of weight-supported arm training combined with computerized exercises with dose-matched conventional training of the UL in 70 subacute patients. Both failed to demonstrate any difference between the 2 methods on arm function and activity. Adie et al. (30) included 209 subacute stroke outpatients in a multicentric RCT. The participants received daily UL rehabilitation with the Nintendo Wii® system or conventional arm exercises. VG rehabilitation was not superior to arm exercises on UL function; also, Wii®, despite being well tolerated, was more expensive than arm exercises at home. Saposnik et al. (31) also drew the same conclusion from the Evrest Study comparing 2 groups of 141 patients with subacute stroke receiving a 2-week program of intensive rehabilitation with commercial non-immersive Nintendo Wii® games compared to the same duration of recreational OT. Those results were synthetized by Laver et al. (32) in a recent Cochrane review including 72 trials and 2470 patients studying the effect of virtual reality (VR) and/or VG-based rehabilitation. Among the 72 trials, the authors selected 22 (1038 patients) comparing VR/VG rehabilitation to the same dose of conventional rehabilitation of the UL. They concluded that "the use of VR and interactive video gaming is not more beneficial than conventional approaches in improving upper limb function".

The main results of our study confirm this conclusion, but it is also possible that the effect of VG was undermined in our study. Our protocol ensured that no lack of chances occurred for patients, so the selective impact of VG was more difficult to reveal because of the multiplicity of common interventions (i.e., when comparing physical therapy + OT + OT vs physical therapy + OT + VG) and also because the additional OT session in the control group included high repetitive and intensive training of the UL. To evaluate whether VR/VG-based rehabilitation has a positive effect, while being more efficient on therapist's investment/costs, it should be studied against "no rehabilitation" or "self-rehabilitation" and not against conventional OT or physical therapy. Kwon et al. (33) studied the effect of VR when added to conventional rehabilitation in a group of 26 patients with acute stroke versus conventional rehabilitation alone and showed a significant effect on motor function (UL-FMS and Function Motor test) in the experimental group. Sin and Lee (34), in a randomized controlled study, compared 2 groups of 40 patients total with chronic stroke, one receiving an additional period of VR rehabilitation of the UL with the Xbox Kinect system®. At the end of the intervention and at follow-up, the 2 groups significantly differed in range of motion, UL-FMS and BBT scores. On the basis of 10 trials (210 participants), Laver et al. (32) concluded that "VR may be beneficial in improving upper limb function and activities of daily function when used as an adjunct to usual care", which suggests that VR/VG as a rehabilitation tool mainly act by increasing the overall therapy time. From this hypothesis, video games could be particularly interesting after discharge from the rehabilitation centre, as a "tele-rehabilitation home-based device", when human resources supporting rehabilitation in the chronic phase are scarce.

One could also suspect that the selection of patients with severe stroke, with UL-FMS < 30/66, influenced the results of our study. However, when considering less impaired patients only (UF-FMS > 20), we did not find any difference between the 2 groups. Furthermore, our sample was similar to comparable studies.

Finally, the small sample size, as well as the discrepancy between the non-significant results on the main judgment criterion (UL-FMS) and the significant positive functional results (BBT), are questioned. These 2 points may suggest an underpowered study. Indeed, the large variability in primary endpoint (UL-FMS) has been underestimated and may have hidden positive results. The choice of the UL FMS as a primary endpoint is also questionable because its metrological properties are controversial, and a more functional criterion could have been more interesting. Not assessing patients' and therapists' opinion on the games prevents us from understanding "external causes" of this negative result.

Nevertheless, a potentially important result of this trial is that early VG-based rehabilitation of the UL could be more efficient for UL motor recovery and function than conventional rehabilitation, when started within the first 30 days after stroke (Fig. 3b). Of course, some caution is required because this conclusion relies on a post-hoc analysis of the main results. Still, because the VG and control groups had similar characteristics at inclusion (Table 1) and different characteristics after early treatment, the VG therapy likely favorably acts on cerebral plasticity and recovery but only when applied early (Fig. 3).

The question of the usefulness of very early (during the first week) or early (during the first month) rehabilitation after stroke has aroused the interest of many authors recently. Because cerebral plasticity is known to be crucial during the first month after stroke (24), some authors suggest that early training, at the right dose and with the correct methods, will aid recovery when applied during this period (35). However, despite an increasing interest, we have limited evidence to guide practice and draw recommendations. We know that very acute rehabilitation may be deleterious immediately (<24 hr) after stroke (36)(37). Some studies support the idea that very early rehabilitation is not useful. For example, the AMOBES Study (38) of an additional 45 min of early intensive physical therapy initiated during the first 72 hr after stroke included 104 patients and reported negative results on motor function as compared with conventional rehabilitation. However, some other studies demonstrated that early mobility training and mobilization appear well tolerated and concluded few reasons to delay initiating some rehabilitation within the first month (24).

So far, the question of a specific effect of VG on motor recovery after stroke remains unsolved. In our study, patients received 2 sessions of UL rehabilitation each day, corresponding to a daily dose of 60 to 120 min of exercises. This dose of UL rehabilitation is very high and exceeds the dose usually used in this population in other studies. Indeed, in 2016, Serrada et al. (39) performed a systematic review of 94 trials including 3236 participants and concluded that only 7.9 min/day was devoted to UL therapy within the 4 weeks of post-stroke rehabilitation. Because our 2 groups of patients were dose-matched, this finding precludes that the increase in motor function and grasping capabilities is linked to the duration and intensity of rehabilitation. We conclude that our study strongly suggests that VG is responsible for this increase of recovery in the early-treated group, which has not been previously studied (32).

Because the answer to each rehabilitation protocol and thus the recovery potential could have differed across groups due to differences in the location of brain lesions, the variability of lesions should be considered. As shown in Table 1, most of our patients had subcortical or total lesions, with no difference between the 2 groups. Except for the fact that damage to the cortico-spinal tract is highly suspected to be associated with reduced UL motor recovery (40), the current literature on the link between lesion characteristics in structural imaging and recovery potential is inconclusive (41). As suggested by some papers in the field, functional MRI as well as diffusion tensor imaging to "structural imaging" should be added in future studies.

Because some characteristics of the VG used in our trial might have influenced the outcome, this work could be continued with an early inclusion and with improved VG. First, even if our patients played a large part of each session with "specifically-designed VGs" that are highly suspected to be more efficient than commercially available ones, they played only 10 min with the most interesting game offering automatic adjustments to their performance. Such "adaptive VGs" have been poorly investigated in the medical literature (42)(7) and their specific interest is seriously suspected, even if not formally demonstrated yet (43).

Second, our VGs were not immersive ones, which could have impeded their efficiency. Indeed, and even if still debated, the immersive properties of VGs are suspected to provide more beneficial results on motor recovery (43).

Third, our games did not include manipulation of visual or auditory feedback provided to patients to favour after-effect and learning, for example by increasing errors in trajectories formation. In the same way, based on mirror neurons theories (44), providing patients with a corrected visual feedback through an avatar could also increase the therapeutic effects of the games.

Fourth, we found a significantly greater improvement in distal UL-FMS with a functional translation in the BBT at 6 weeks in the VG group (Table 3). This result is somewhat surprising because all the games in the VG group mainly involved shoulder-elbow movements. However, half of the games were played with a mouse-like device, so distal extensors and pinch muscles probably played an important role in controlling the movement in the game space. Thus, patients in the VG group may have learned to use the distal joints while playing VGs with a mouse-like playing interface, so that VG therapy reduced under-use of the distal joints.

Conclusion

Considering all patients, our study is inconclusive about the hypothesized superiority of VG-based rehabilitation of the UL as compared with the same duration of conventional OT in patients with subacute stroke. This finding suggests that in general, VG-based methods should not replace conventional methods but can be considered additional therapy, thus increasing the amount of rehabilitation.

Considering only patients for whom rehabilitation started within 30 days post-stroke, our study concludes that VG-based UL rehabilitation is more effective than conventional rehabilitation. Although the latter result needs to be confirmed by further studies, this finding suggests that early after stroke, VG therapy may be effective and could be systematically considered a complement to conventional methods.

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Conflict of Interest. None declared.

Legends

Figure 1. Flow of participants in the study.

Figure 2. Neurological and functional changes in the video game and control groups.

Figure 3. Neurological and functional changes by intervention delay.

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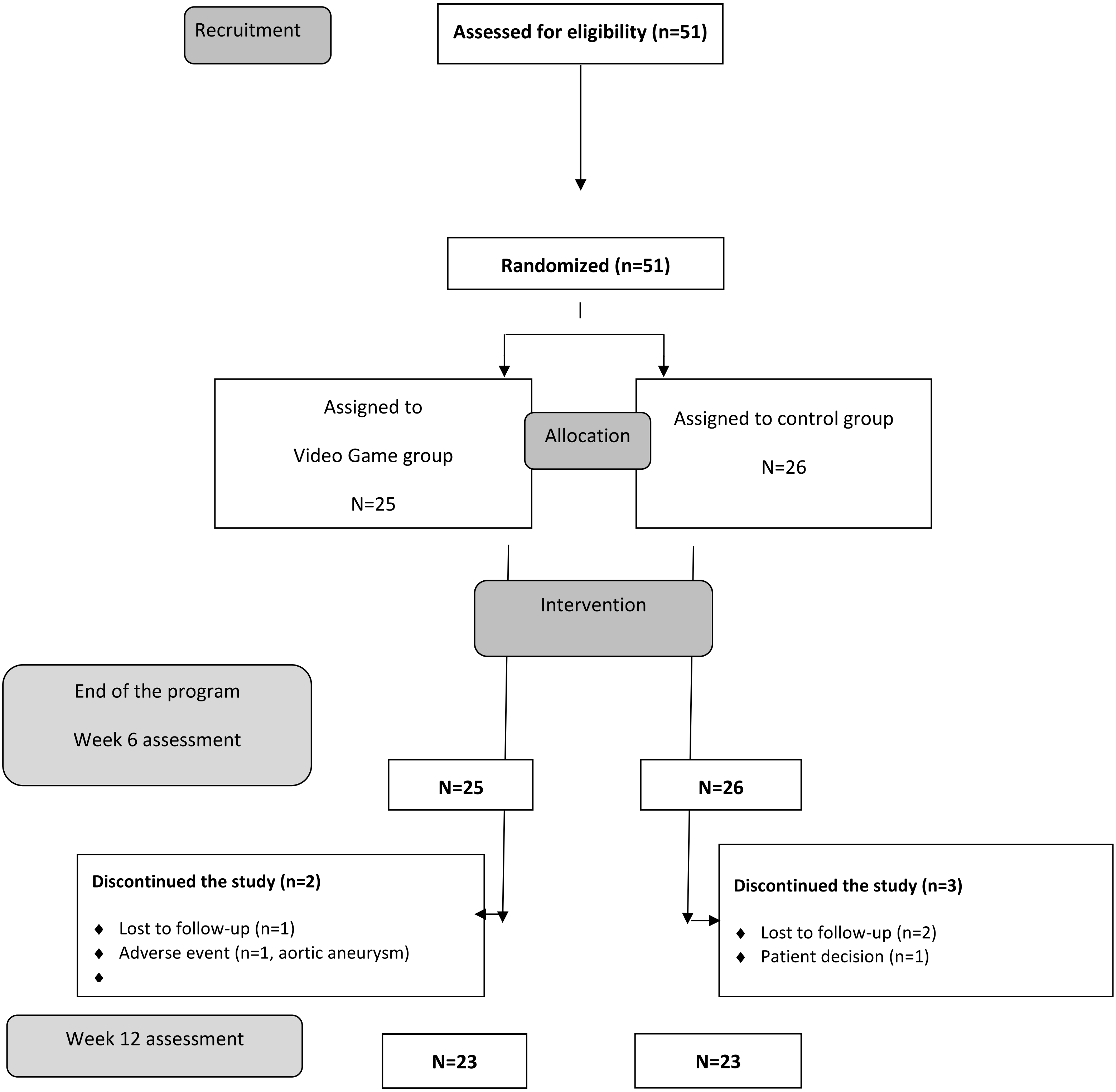
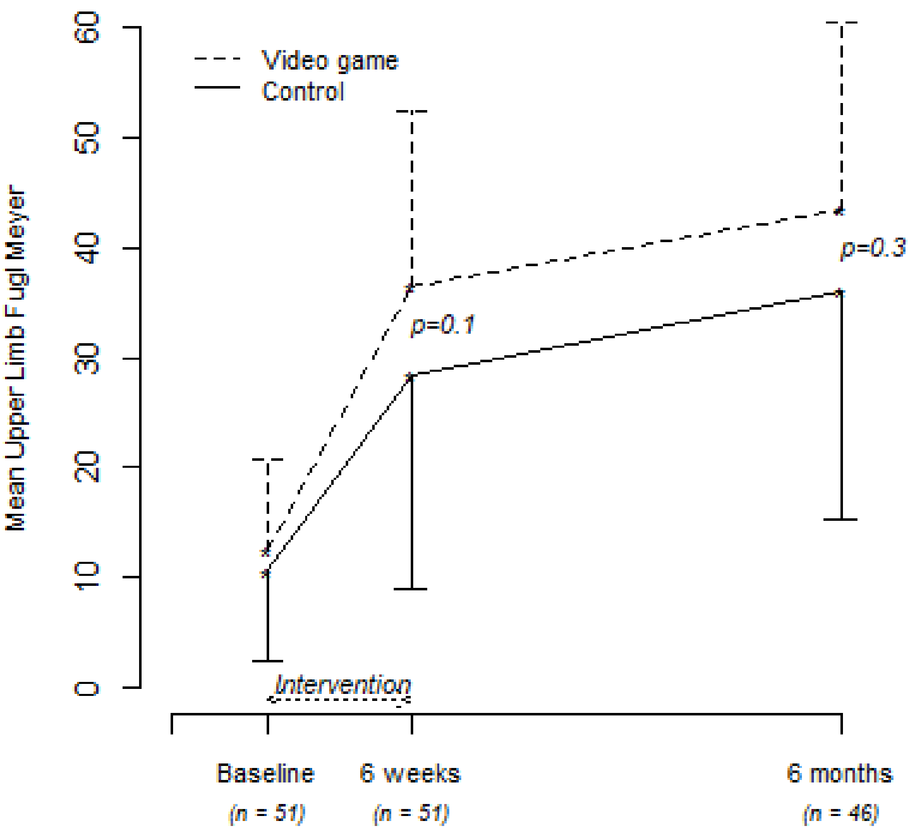
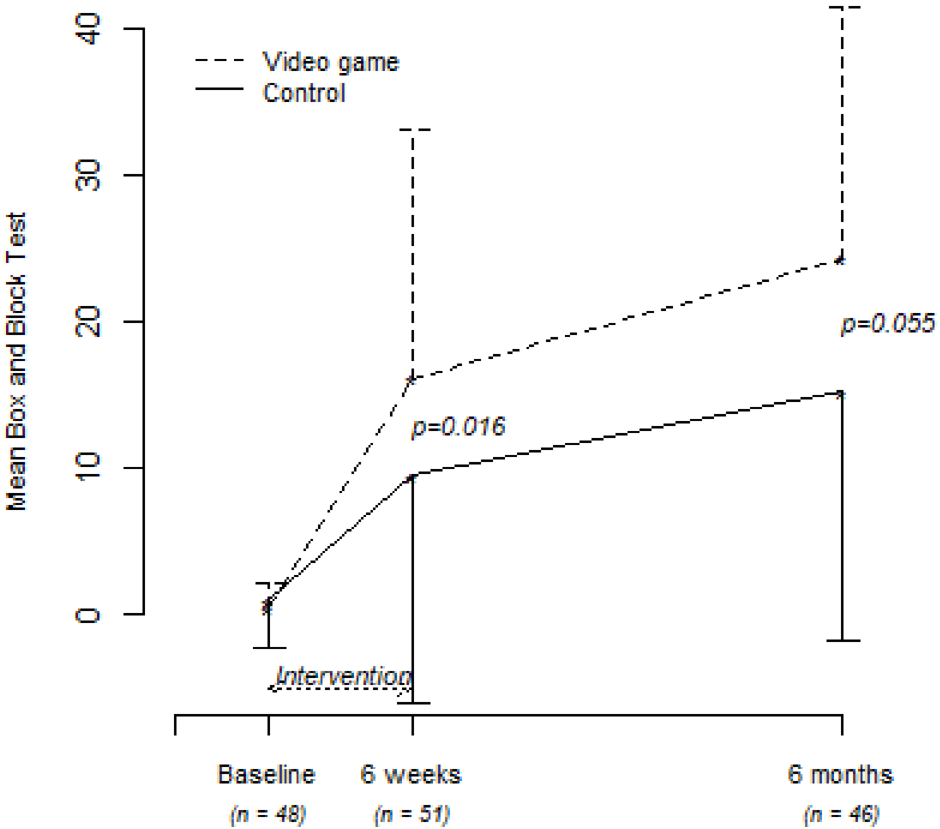

Recruitment
Assessed for eligibility (n=51)
Randomized (n=51)
Assigned to
Video Game group
N=25
Allocation
Assigned to control group
N=26
Intervention
End of the program
Week 6 assessment
N=25
N=26
Discontinued the study (n=2)
Lost to follow-up (n=1)
Adverse event (n=1, aortic aneurysm)
Discontinued the study (n=3)
Lost to follow-up (n=2)
Patient decision (n=1)
Week 12 assessment
N=23
N=23


Mean Upper Limb Fugl Meyer
0
10
20
30
40
50
60
Video game
Control
p=0.1
p=0.3
Intervention
Baseline
(n = 51)
6 weeks
(n = 51)
6 months
(n = 46)
Fig2a


Mean Box and Block Test
0
10
20
30
40
Video game
Control
p=0.016
p=0.055
Intervention
Baseline
(n = 48)
6 weeks
(n = 51)
6 months
(n = 46)
Fig2b

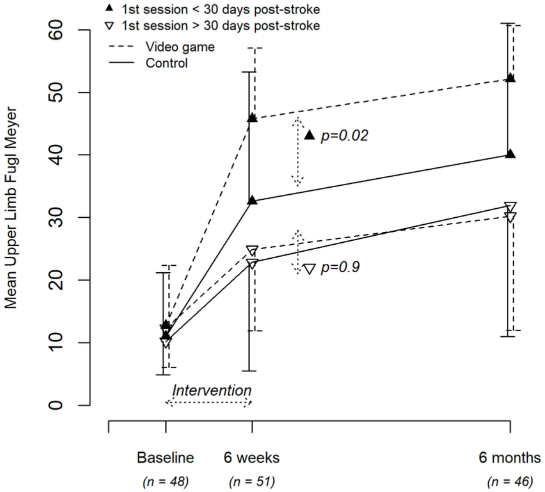

1st session < 30 days post-stroke
1st session > 30 days post-stroke
Video game
Control
Mean Upper Limb Fugl Meyer
0
10
20
30
40
50
60
p=0.02
p=0.9
Intervention
Baseline
(n = 48)
6 weeks
(n = 51)
6 months
(n = 46)

Fig3a

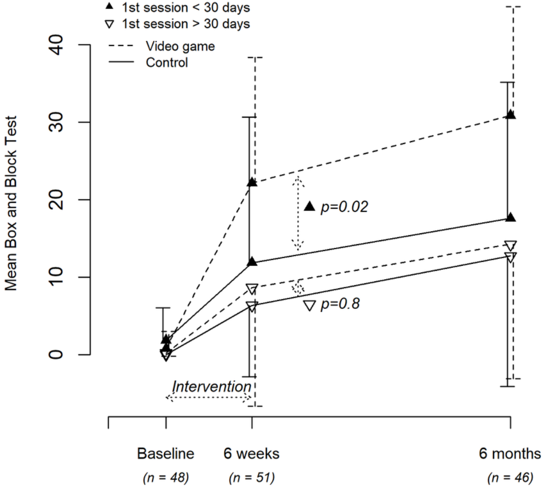

1st session < 30 days
1st session > 30 days
Video game
Control
Mean Box and Block Test
0
10
20
30
40
p=0.02
p=0.8
Intervention
Baseline
(n = 48)
6 weeks
(n = 51)
6 months
(n = 46)

Fig3b

Table 1. Patient characteristics at inclusion for the control and video games groups.

		Control group (n=26)	Video games group (n=25)
Sex	◦ **Female**	11 (42%)	9 (36%)
	◦ **Male**	15 (58%)	16 (64%)
Stroke side	◦ **Right**	12 (46%)	13 (52%)
	◦ **Left**	14 (54%)	12 (48%)
Stroke type	◦ **Ischemic**	16 (65%)	22 (88%)
	◦ **Haemorrhagic**	10 (35%)	3 (12%)
Stroke lesion	◦ **Cortical**	1 (5%)	0 (0%)
	◦ **Sub Cortical**	6 (29%)	9 (47%)
	◦ **both**	4 (19%)	7 (37%)
Age (yr)		55.8 (14.0) 56.47 [15.16]	60.8 (14.1) 64.22 [20.77]
NIHSS		11.6 (6.1) 12 [8]	9.5 (4.5) 9 [4]
Time since stroke (d)		27.5 (19.4) 20.5 [23]	27.0 (19.9) 22 [26]
UL Fugl-Meyer Proximal		7.9 (5.2) 6 [5]	9.9 (5.1) 8 [7]
UL Fugl-Meyer Distal		2.8 (4.7) 0.5 [4]	2.6 (4) 1 [5]
UL Fugl-Meyer Total		10.7 (8.3) 6.5 [12]	12.5 (8.2) 9 [12]
BBT affected arm		1.0 (3.3) 0 [0]	0.5 (1.7) 0 [0]
WMFT time		81.0 (41.8) 82.83 [67.13]	88.6 (41.3) 112.80 [52.00]
WMFT functional ability		0.7 (0.8) 0.47 [1.20]	0.58 (0.8) 0.20 [0.93]
MAL amount of use		0.1 (0.1) 0.00 [0.07]	0.2 (0.6) 0.00 [0.00]
MAL quality of movement		0.04 (0.1) 0.00 [0.00]	0.2 (0.5) 0.00 [0.07]
Barthel Index		46.2 (25.2) 40 [30]	48.0 (23.9) 45 [40]
SF36 Physical Composite Score		30.6 (5.7) 30.27 [9.40]	31.7 (5.5) 31.42 [10.16]
SF36 Mental Composite Score		39.7 (14.3) 34.37 [20.29]	43.9 (11.1) 41.98 [17.34]

Data are mean (SD) and median [Q1–Q3].
NIHSS, National Institute of Health Stroke Score (worse score = 42); UL, upper limb; BBT, Box and Block Test; WMFT, Wolf Motor Function Test; MAL, Motor Activity Log; SF36, Medical Outcomes Study Short Form 36.
Note that stroke lesion data were missing for some patients (n=11).

Table 2. Rehabilitation sessions for the control and video games groups during the 6-week intervention.

	Control group (n=26)	Video games group (n=25)
Standard care sessions (provided to both groups)		
Physiotherapy: total number	33.6 (8.4)	32.6 (9)
Physiotherapy: duration (min)	55.5 (7.8)	55.4 (8.3)
Occupational therapy: number	32.8 (8.5)	31.5 (9.4)
Occupational therapy: duration (min)	28.9 (4.2)	29.5 (4.1)
Speech therapy: number	12.3 (11)	8.8 (10)
Speech therapy: duration (min)	31.8 (5.5)	32 (6.1)
Additional sessions (different in the 2 groups)		
Number of sessions	32.7 (8.7)	32.7 (8.9)
Duration (min)	29.3 (4.3)	28.5 (4.4)
Nature of intervention	Occupational therapy	Video games

Data are mean (SD).

Table 3. Gains in upper limb motricity, function, independence, quality of life at 6 and 12 weeks in the control and video games group.

Assessments	**Difference: week 6 from baseline**				**Difference: month 6 from baseline**			
	Control (CR)	Video games (VG)	Number evaluated (CR/VG)	p	Control (C)	Video games (VG)	Number evaluated (CR/VG)	p
UL Fugl-Meyer Proximal	11.7 (10.2)	13.4 (9.5)	26/25	0.5	15.7 (10.2)	18.2 (9.4)	23/23	0.4
UL Fugl-Meyer Distal	6.2 (6.0)	10.7 (6.4)	26/25	0.02	9.9 (7.5)	13 (7.9)	23/23	0.3
UL Fugl-Meyer Total	**17.8 (14.6)**	**24.1 (14.8)**	**26/25**	**0.1**	**25.6 (16.3)**	**31.2 (15.8)**	**23/23**	**0.3**
BBT affected arm	7.4 (12.2)	15.7 (16.3)	23/25	0.02	14.4 (15.5)	23.8 (16.7)	21/23	0.055
WMFT time	-30.7 (39.7)	-47.3 (42.1)	25/25	0.16	-43.1 (37.1)	-56.8 (45.4)	22/23	0.39
WMFT Proximal functional ability	1.3 (1.2)	2.1 (1.4)	25/25	0.05	1.9 (1.3)	2.6 (1.6)	22/23	0.13
Nine-Hole Peg (sec)	-3.6 (5.5)	-13.4 (56.1)	23/25	0.7	-4.1 (5.5)	-14.3 (58.3)	21/23	0.5
MAL amount of use	0.8 (1.3)	1 (1.6)	25/25	0.5	1.3 (1.5)	2.2 (2)	22/23	0.2
MAL quality of movement	0.7 (1.1)	1 (1.5)	25/25	0.5	1.2 (1.4)	2 (1.8)	22/23	0.2
Barthel Index	28.6 (18.2)	33.4 (25.4)	25/25	0.4	42.7 (21.4)	40.9 (25.7)	22/23	0.8
SF36 Physical Composite Score	2.4 (8.5)	2.8 (6.5)	25/23	0.9	7.6 (8.8)	7 (9.7)	21/22	0.8
SF36 Mental Composite Score	3.6 (11.4)	2.9 (12.2)	25/23	0.8	1 (11.2)	2.8 (15.3)	21/22	0.7

Data are mean (SD).
Primary efficacy criterion = gain in UL Fugl-Meyer Total.
p-values correspond to Student *t* or Wilcoxon tests comparing gains (6 weeks and 6 months from baseline) between the 2 groups.
UL, upper limb; BBT, Box and Block Test (mean number of blocks); WMFT, Wolf motor function test; MAL, motor activity log; SF36, Medical Outcomes Study Short Form 36