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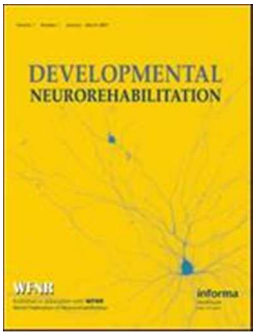

Remind to move - A novel treatment on hemiplegic arm functions in children with unilateral cerebral palsy: A randomized cross-over study

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TITLE: Remind to move - A novel treatment on hemiplegic arm functions in children with unilateral cerebral palsy: A randomized cross-over study

ABSTRACT

Objective: To investigate the effects of 'remind to move' treatment on hemiplegic arm function in children with unilateral cerebral palsy (CP).

Methodology: Twelve students with unilateral CP aged 6 to 18 were recruited from a special school and randomly assigned into two groups. Participants in the experimental group underwent a 3-week sensory cueing treatment followed by a 3-week sham treatment. Participants in the waitlist group completed the sham treatment first followed by the sensory cueing treatment. There was a four-week washout period between treatments.

Results: Both functional hand use and arm impairment level significantly improved after the 3-week sensory cueing treatment for the combined sample between groups. However, no significant carryover effects were found for either treatment.

Conclusion: Three weeks of 'remind to move' treatment is useful in improving hemiplegic arm function and quantity of hand use in children with unilateral CP but the long-term carryover effect requires further investigation.

Keywords: Unilateral cerebral palsy, hemiplegia, developmental nonuse, sensory cueing, upper limb task practice

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Introduction

Cerebral palsy (CP) is a common group of childhood motor and postural impairments. Its prevalence ranges from 1.5 to more than 4 per 1000 live births or children worldwide [1-6]. Hemiplegia, characterized by a clinical pattern of unilateral motor impairment, is a common type of CP, accounting for about one third of all children with unilateral CP [7]. It involves the upper more than the lower extremity, with symptoms of spasticity, weakness and sensory deficits, as well as difficulty with the timing and coordination of reaching and grasping during precision movements [8].

When growing up, children with unilateral CP often learn strategies to manage daily tasks (such as play) with the less affected hand. They may gradually neglect their more affected hand due to a lack of normal sensorimotor experiences and negative experiences of using it, even if the impairment is only mild [9-11]. This phenomenon in children is referred to 'developmental nonuse or disregard' [12], which is akin to the learned nonuse reported in the literature on adults who have sustained a stroke [13]. Such learned nonuse may be a different phenomenon in children who sustain an early brain lesion, despite the appearance of similar behavioural mechanisms of reinforcement of the uninvolved hand and suppression of use of the involved hand as have been identified in adults [14]. Unlike an adult who suffers neurological impairment later in life, a child with hemiplegia has not experienced normal arm movement, leading to the development of motor arm function that is already inhibited. Rehabilitation must, therefore, create an opportunity, experience and environment in which such children can learn how to use their

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involved arm, as well as reverse the behavioural suppression of the use of the affected arm and reinforce its use to perform even the simplest task, such as stabilizing an object [12, 15].

Rehabilitation for children with unilateral CP focuses on improving the functional performance and actual use of the more affected arm. Constraint-Induced Movement Therapy (CIMT), which involves intensive, repetitive and task-specific forced use of the involved arm while the other one is constrained, has emerged as a plausible approach to improving the capacity of the more affected limb [8, 15-17]. Numerous randomized controlled trials have consistently demonstrated that CIMT is superior to standard care at lower dosages in improving upper limb (UL) function in children with unilateral CP [9, 10, 12, 18-28]. In contrast, minimal differences in training effects have been found when comparing CIMT to an equivalent dose of intensive bimanual arm training or goal-directed occupational therapy [23, 26, 29]. A recent review also indicates that both CIMT and bimanual arm training produce similar improvements in the bi- and unimanual capacities of the affected arm and in overall functional performance [30]. This indicates that intensive guided practice or structured shaping, rather than simply forced use or arm restraint, may be the critical ingredient in improvement [31].

CIMT has its own limitations. Intensive external verbal and physical promotion is often required to force children to properly practice the training tasks at times other than when they are restrained [18]. Most importantly, CIMT only focuses on unimanual tasks and does not allow practice of bimanual activities, although the goals

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identified by children and parents tend to involve the latter [23, 28]. This has raised doubt as to whether its effects can be transferred into daily life through similarly intensive practice involving external sensory cues on the impaired arm rather than a restraint on the unaffected one [8, 31].

Two recent studies have explored the effects of using external sensory signals from an ambulatory device in the form of a wristwatch to provide sensory cueing, together with appropriate repetitive training, for hemiplegic UL in adults with stroke [32, 33]. Another recent study using a single-subject pre/post comparison shows that sensory cueing with repetitive practice of affected arm functions improved arm efficiency and overcame learned nonuse of the hemiplegic hand among children with unilateral CP in daily activities [34]. With reference to this pilot study, using a randomized cross-over design and a sample of double the size, set out to investigate whether this new and child-friendly treatment – 'remind to move', a 3-week sensory cueing treatment involving repetitive practice of tasks involving hemiplegic UL functions – outperforms a sham treatment in students with unilateral CP. Since this is a novel treatment developed by the investigators, the results of this study can be used as a reference to calculate the sample size for a future randomized controlled trial.

Methodology

Participants

A total of 12 students with unilateral CP were recruited by convenience sampling from a special school for children with physical disabilities in Hong Kong. The potential subjects were then screened by the school's occupational therapists (OTs) for

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eligibility for inclusion in the study, using the inclusion criteria below.

With reference to the previous preliminary study [34], the inclusion criteria were; (a) aged 6 to 18 years; (b) able to complete all the assessment procedures and follow commands in training; (c) able to perform some grasp and release functions with the hemiplegic hand; (d) able to perform an active wrist extension of 20° and a finger extension of 10° for each digit from full flexion. These criteria are similar to those described in previous CIMT studies [9, 10, 12]. Apart from that, we also required the following; (e) parents prepared to provide informed consent for their child to participate; and (f) having received no new pharmaceutical interventions, such as dorsal rhizotomy and botulinum toxin injections, and/or no new surgical interventions, within the six-month period prior to admission to the study.

The exclusion criteria included; (a) having an intellectual disability such that simple tasks could not be understood or executed (that is, a developmental age of less than two years); (b) predominant spasticity and/or muscle contracture with scores on the Modified Ashworth Scale (MAS) [35] of more than grade 3 on wrist flexors, forearm pronators and/or thumb adductors.

This study was approved by the human studies committees of the Hong Kong Polytechnic University (HSEARS20111021009) and the Management Board of the special school involved. Informed consent forms were signed by the parents/guardians of all the participants.

Study Design and Procedure

This was a prospective, single-blinded and randomized cross-over study. Participants

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were matched into pairs by a case occupational therapist and assigned to either the experimental or waitlist group according to their grades of the hand function on actual performance of handling objects of the Manual Ability Classification System (MACS) [36]. Two participants were at Level I, 6 at Level II, and 4 in Level III. They were randomly assigned using a computer-generated sequence. Those assigned odd numbers went into the experimental group (which underwent a 3-week sensory cueing treatment with a set of repetitive UL tasks) and those with even numbers entered the waitlist group which received a 3-week sham treatment.

To minimize the treatment effect, a four-week washout period (that is, no treatment) was arranged between both treatments. After the break, participants who had previously been assigned to the experimental group and who had received the sensory cueing treatment were assigned the sham treatment, whereas those in the waitlist group who had completed sham treatment received the sensory cueing treatment (Figure 1).

Insert figure 1 about here

In the experimental treatment, participants wore a sensory cueing wristwatch (SCW-V2[a]) on the more-affected arm which was set to emit a vibration signal every 15 minutes. They completed a set of tailor-made repetitive UL movement tasks whenever they felt the vibration cueing. This went on for six hours per day (from their arrival at school until their departure), 5 days per week for 3 weeks. The wristwatch device (SCW-V2[a]) is designed to provide pertinent vibration signals to patients with hemiplegia in order to increase their awareness of the paretic limb [32-34]. The

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tailor-made UL movements for each subject were designed according to their specific upper limb impairments in the MACS [36] as specified by a trained occupational therapist. The tasks were repetitive and discrete movements carried out through shaping and functional activities, including manipulation tasks (opening hands or making fists), range of motion tasks (active flexion/extension of the shoulder/elbow/wrist, forearm pronation/supination), and fine motor tasks, such as turning cards in the hand (Table 1), and were taught by the case occupational therapists from the school. For the sham treatment, the participants were encouraged to wear the same device on the involved arm but no sensory cueing signal was emitted. They completed conventional therapy for an hour a day, 5 days a week across the same 3-week period and were also told to use their involved arms as much as possible.

Insert table 1 about here

The investigators, who conducted the outcome measures, were blinded to the treatment provision. Assessments were carried out without any device being present and the participants were told not to tell the assessor what treatment they had received. All participants were assessed one day before the treatment had started and one day after it had ended. In addition, caregivers were invited to evaluate the participants' functional performance at home.

Outcome Measurement

Outcome measures were selected that would provide results at three levels [5]; (1) UL efficiency, (2) functional hand use and (3) UL impairment levels. Each student was

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assessed pre- and post-sensory cueing and sham treatment, respectively, by an investigator who was blinded to group allocation.

With reference to our previous study [34], the subtest 3 (Manual Dexterity and Speed test) of the Bruininks-Oseretsky Test of Motor Proficiency (2nd edition) (BOTII) [37, 38] was selected as the outcome measure to assess UL efficiency. The subtest 3 of BOT-II consists of uni- and bimanual tasks (making dots in circles, transferring pennies, placing pegs into a pegboard, sorting cards and stringing blocks). The unimanual tasks are to be executed by the more- rather than the less-affected hand.

To assess the actual functional use of the hand, the SCW-V2[a] has a built-in accelerometer to detect the amount of upper extremity movement in the X, Y and Z directions sampled at 5 Hz and using a two-second recording epoch time. In addition, the Caregiver Functional Use Survey (CFUS) was selected to evaluate functional use of the more-affected UL. The CFUS is a reliable semi-structured interview designed to assess caregivers' perceptions of how much (quantity of hand use) and how well (quality of hand use) their children have used the involved upper extremity to perform 14 bimanual tasks in their real-life environment [9, 39]. The items of the CFUS were derived from the Motor Activity Log [40] which is a tool originally developed for adults with stroke. The CFUS has the advantage than the Paediatric Motor Activity Log (PMAL) used in a previous study [34] because it can be applied to school-aged children whereas the PMAL is mainly applied to capture the spontaneous arm use for younger children aged 7 months to 8 years [41, 42]. In the present study, the primary

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caregivers, who were aware of the group allocation, were invited to evaluate the actual use of the involved hand at home using the CFUS.

The UL impairment measures involved power and pincer grips strength as well as active range of motion (AROM) on the upper extremity which includes shoulder flexion, elbow flexion, forearm pronation/supination and wrist flexion/extension. All movements were evaluated using the Biometrics dynamometer and pinch meter and the digital goniometer within the E-LINK[b] Evaluation System (Biometrics H500 Hand Kit and Biometrics R500 ROM Kit). The E-LINK Evaluation System is a computer-based standardized evaluation of the upper extremities. It is sensitive to detecting slight changes of strength and range of motion. It also accurately measures the standard peak grip force and pinch strength with an automatic calculation of the average and coefficient of variation.

Statistical Analysis

All statistical analyses were performed using SPSS version 19.0[c]. The level of significance of all tests was set at $p<0.05$ for one-tailed analysis. Parametric statistics were used to evaluate the carryover and treatment effect as the outcomes measured in this trial yielded normally-distributed continuous data (according to the Shapiro-Wilk or Kolmogorov-Smirnov tests) [3, 44]. Chi-square and paired *t*-tests were used to measure differences in the baseline data and demographic variables between the experimental and waitlist groups.

The carryover effect considers whether the impact of the sensory cueing treatment was still present when the participants in the experimental group commenced the sham

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treatment period. This was assessed using the mean (and 95% confidence interval) of the difference between the evaluations at baseline and the end of the washout period. The treatment effect considers the benefit of sensory cueing in the therapy and sham treatment, and was assessed using paired *t*-tests to compute the mean change pre- and post-treatment in the combined sample [45, 46]. Between-groups differences were also investigated, using independent *t*-tests, to compare the treatment effect of the sensory cueing and sham treatments for the total sample [45, 46].

Results

Table 2 presents the demographic data on the participants including age, gender, IQ score, MACS score and SCW-V2[a] data output. Twelve participants (seven males and five females; four with left- and eight with right-sided hemiplegia; six of normal intelligence, three with mild and three with moderate intellectual impairment) with hemiplegic CP completed the study. Their ages ranged from six to 18 years, with an average of 13.08±4.44. Two were classified in Level I for the MACS (16.7%), 6 in Level II (50%) and 4 in Level III (33.3%). The SCW-V2[a] data output, showing compliance with the experimental treatment, indicated that seven of the participants had been absent for one or two days due to sickness absence, examinations or school outings. Only one subject had completed the treatment for almost 6 hours (5.9) daily, three had achieved nearly 5 hours (25%) and six had spent fewer than 2 hours (50%). The mean number of total upper extremity movements per day showed that five participants had moved their more-affected arms more than 2000 times a day, one had moved about 1300 times and six had moved fewer than 400 times daily.

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Insert table 2 about here

Table 3 shows the mean and standard deviation for the continuous variables, the frequency distribution (percentage) for the categorical data and the results of the demographic comparison between the experimental and waitlist groups. There was no difference in demographic profile between the two groups. Participants in the experimental group had moved 1665 times per day with a total movement duration of 3.2 hours, while those in the waitlist group had moved less (1127 times in 2.2 hours).

Insert table 3 about here

Table 4 shows the means and standard deviations of the UL efficiency, functional hand use, and arm impairment level at each measurement occasion. The results of baseline comparison, carryover and treatment effects for each dependent variable were shown in Table 5. There were no significant differences in the baselines between groups. In terms of the carryover effect, no significant differences were found between the sensory cueing and sham treatments when the mean changes between the baseline and the end of the washout period were compared across the two groups (Table 5).

Insert table 4 and table 5 about here

The treatment effect in the combined sample is shown in Table 5. Firstly, the pre- and post-sensory cueing treatment effect showed a significant improvement in functional hand use. This is indicated by the CFUS quantity (from 27.82±8.14 to 32.17±8.11; $p<0.001$) and quality (from 26.67±7.94 to 29.25±7.76; $p=0.001$) measures, as well as a significant increase in AROM for shoulder flexion (from

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133.75±13.5 to 141.25±15.4; p=0.002) and wrist extension (from 32.17±18.98 to 35.83±18.93; p<0.001) was found immediately after 3-week sensory cueing treatment. However, no significant changes in UL efficiency or grip strength were identified. No significant differences were found pre- and post-sham treatment combined with conventional therapy. Secondly, when comparing the effects of the sensory cueing treatment and the sham treatment combined with conventional therapy, there were significant improvement in functional hand use as shown by the CFUS quantity score (p=0.028), and in level of arm impairment as indicated by the AROM for shoulder flexion (p=0.012).

Discussion

This study investigated a novel treatment – 'remind to move' – for hemiplegic UL in participants with unilateral CP with mild to severe hand disabilities. Noticeable improvements in functional hand use and UL impairment were found after a 3-week sensory cueing treatment compared to a sham intervention. The improvement in functional hand use was indicated by increased scores on the CFUS, and UL motor performance was shown by an increase in the active ROM for shoulder flexion and wrist extension. Therefore, the results support the proposition that sensory cueing with limb activation treatment is useful in improving hemiplegic UL function in children with unilateral CP. This is consistent with the findings of a previous preliminary study applying the same treatment to adults with stroke [32]. Moreover, the findings of this cross-over trial indicate that the 'remind to move' treatment is

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superior to the sham treatment in children with unilateral CP.

A concern of paediatric CIMT studies is that the choice of restraints should be child-friendly. Children generally do not like their arms to be restrained, while this is less likely to be crucial for adults who tend to be more compliant and prepared to tolerate discomfort [47, 48]. Another concern for children is safety, with previous studies of CIMT recommending against wearing a restraint on the uninvolved hand when at home [8, 47]. The introduction of this innovative and child-friendly treatment, using a wristwatch device with a built-in recording function worn on the hemiplegic arm to enhance movement initiation, is likely to be welcomed by children with unilateral CP. Moreover, we encountered no adverse events associated with children wearing the portable wristwatch. The continuous vibration cueing every 15 minutes reminded them to be aware of and move their hemiplegic UL intensively, and thus increased the quantity of the movement of their involved arm. This treatment also has the advantage that it can be easily incorporated into conventional interventions for children through play and self-care at home or in school. The CIMT mainly focuses on unimanual UL practice, although more recent studies have incorporated a certain amount of time for bimanual practice during play and self-care activities [18]. The new treatment in this study leaves participants with both hands free. This not only protects them from losing their balance while walking, but also leaves the less-affected hand free to be used in bimanual tasks that are essential to activities of daily living.

Contrary to the improvement in functional arm use and UL impairment, the change

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in UL efficiency pre- and post-sensory cueing intervention was not significant. This is inconsistent with the findings of a previous study [34] which reports significant improvement in the UL efficiency of children with hemiplegic CP as measured by the Jebsen Hand Function Test (JHFT) and the BOT-II subtest 3. In that study the treatment effect was maintained 3 weeks after sensory cueing treatment using the SCW-V2 with repetitive arm movement. This may be because the previous study involved a single small group, and/or because of the flooring effect on the levels of moderate to severe hand impairment measured using MACS among the participants in this study. Another possible reason for the difference in results is that the compliance of movement upon cueing of the more-affected arm (mean±SD=5.6±0.4 hours/day) [34] is about two times more than that of the present study (mean±SD=2.7±1.9 hours/day). This finding implies that high intensity of arm practice may induce more improvement on the arm efficiency of the more-affected arm.

Although there was an improvement on the amount and quality of hemiplegic UL within groups and the significant increase in quantity of use between groups revealed by the CFUS immediately after 3-week sensory cueing treatment, compared with the sham treatment the absence of an overall improvement in quality of hand use and UL efficiency was disappointing. One of the possible reasons is that the "remind to move" treatment did not involve very active therapist involvement and children were prompted to practise the movement tasks by themselves which might not be sufficient to promote the UL efficiency and quality of hand use during daily tasks. In future studies, increase in therapists' supervision during treatment and parents' involvement

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at home should be considered to maximize the treatment effects and to induce changes in quality of use of hand functions in daily life.

The duration and number of movements of the affected arm among the participants in the experimental group in this study were higher than for the waitlist group, although the difference was not statistically significant. One of the possible explanations for this is that the effect of a 3-week sensory cueing intervention with repetitive arm practice may be transferred into a natural context, so the participants spontaneously used their more-affected hand in daily life even when there was no sensory cueing (that is, during the sham treatment period). The levels of intellectual impairment found among the participants in this study may also have influenced the extent to which they performed the intervention tasks. Even among participants with the same level of UL functionality, those with mild to moderate intellectual impairment moved the involved arm less often and for shorter periods than those with normal IQ. This implies that the presence of intellectual impairment may preclude the compliance of children to participate in "remind to move" intervention.

In contrast to the overall improvement in AROM for shoulder flexion and wrist extension found in this study, there were no significant changes in grip strength at the arm impairment level. This is consistent with previous studies [27, 34] showing no significant increase in grip strength after sensory cueing treatment or CIMT. However, the significant improvement in AROM was a surprise, as a recent study [26] shows no changes on any impairment measures after CIMT or bimanual training. Therefore, the results suggest that the use of repetitive and simple tailor-made arm movement tasks

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may benefit motor control of hemiplegic UL, rather than increasing grip power, in children with moderate to severe hand impairment.

There were several limitations to this study. Its generalizability is limited given the use of a convenience sample from a single special school and the small sample size. Replication of this study using a larger sample with a longer treatment period, to examine longer term outcomes in a randomized controlled trial, would be beneficial. Another limitation is the comparatively large variations in age and UL functional level among the small sample. Finally, muscle strength in the arms and forearms, apart from grip strength, was not measured. Future studies should employ a more robust design with better control of the potentially confounding variables (such as age, level of spasticity and IQ) and use a more homogenous group of participants with mild to moderate UL functionality to study the possible benefit of the sensory cueing treatment to this population and using more valid and reliable measures to capture the UL efficiency and school activities participation.

Conclusion

This study suggests that the 'remind to move' treatment, incorporating both sensory cueing and limb activation, benefits the use of the hemiplegic arm in children with unilateral CP. It provides information on an alternative approach which may be used interchangeably with other treatments of the hemiplegic UL (such as CIMT or forced use therapy) in such children. Further studies using a randomized controlled trial method are necessary to compare the effect of the 'remind to move' treatment with CIMT in children with hemiplegic CP, and to investigate the dosage in order to

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determine carryover.

(Words 3,911)

Supplier

a. PolyU Technology & Consultancy Co Ltd, QR603, The Hong Kong Polytechnic University, Hung Hom, Hong Kong (US patent - US-2010-0160834-A1).

b. E-LINK Evaluation System, Biometrics Ltd (UK), Nine Mile Point Ind. Est., Newport, United Kingdom

c. SPSS Inc., 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

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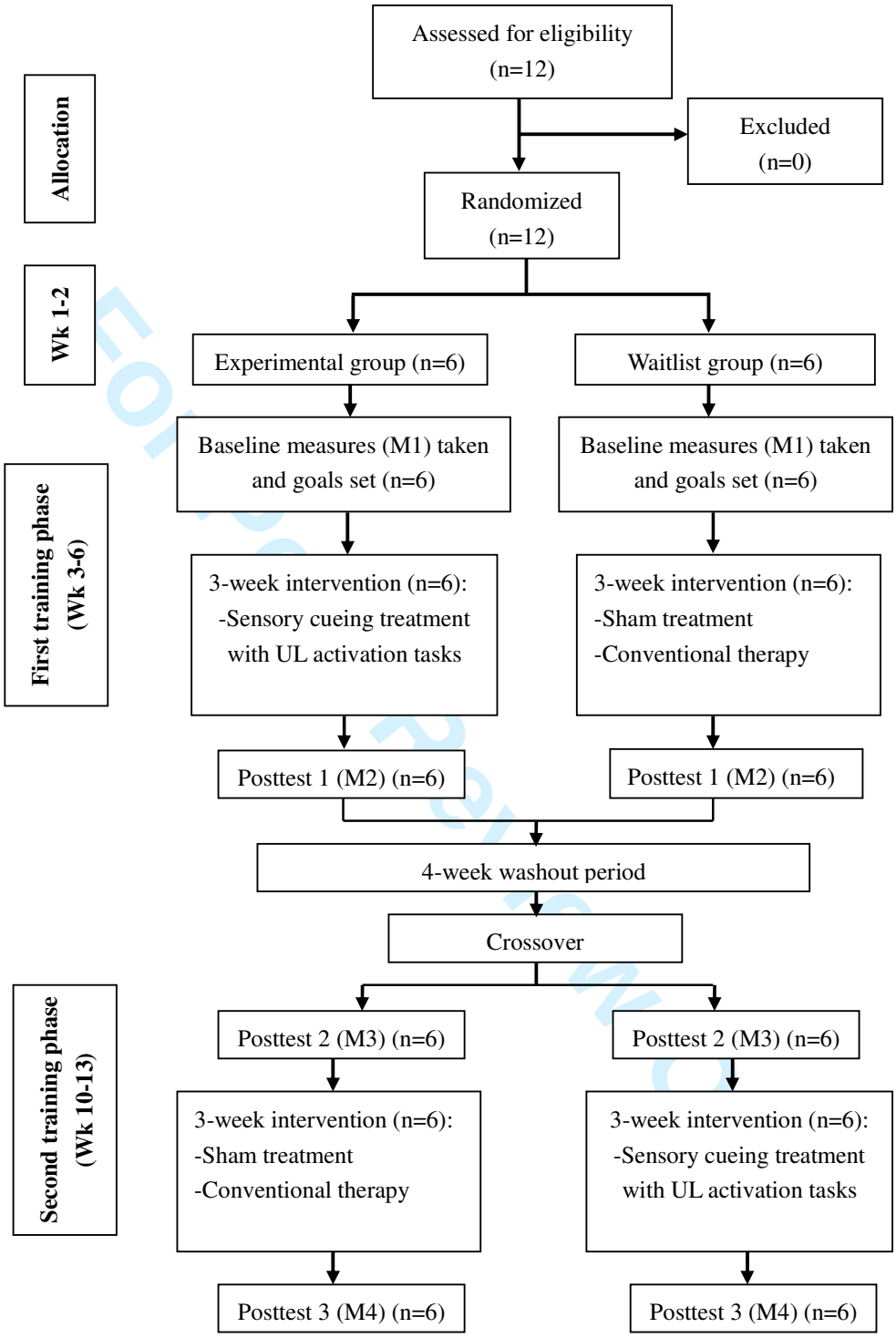

Figure 1. Flowchart diagram

Table 1. Tailor-made tasks for hemiplegic upper limb

Participants	MACS level	Customary tasks for UL (times per 15 minutes)
HHK	III	Turning cards (Forearm pro. / sup.×10), Opening hand and making fist ×10
LHY	I	Turning cards (Forearm pro. / sup.×10), Cleaning table (Elbow F/E with Shoulder F/E ×10)
WTK	II	Turning cards (Forearm pro. / sup.×10) Opening hand and making fist ×10
CSH	III	Elevating arm (Shoulder F/E×10), Elbow F/E×10
CHY	II	Turning cards (Forearm pro. /sup.×10), Cleaning table (Elbow F/E with Shoulder F/E ×10)
FLL	II	Elevating arm (Shoulder F/E×10), Cleaning table (Elbow F/E with Shoulder F/E ×10)
SKH	III	Turning cards (Forearm pro. /sup.×10), Elbow F/E×10
WKS	II	Turning cards (Forearm pro. /sup.×10), Cleaning table (Elbow F/E with Shoulder F/E ×10)
AKW	II	Turning cards (Forearm pro. /sup.×10), Cleaning table (Elbow F/E with Shoulder F/E ×10)
CWH	III	Turning cards (Forearm pro. /sup.×10), Elevating arm (Shoulder F/E×10)
CKW	I	Turning cards (Forearm pro. / sup.×10), Manipulation with wrist extension ×10
LKC	II	Turning cards (Forearm pro. /sup.×10), Manipulation with wrist extension ×10

MACS, Manual Ability Classification System; UL, upper limb;
pro./sup., pronation/supination; F/E, flex/extension

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Table 2. Demographics and treatments of participants

Group	Name of subjects	Age (yrs)	Gender	Hemi side	MACS level	IQ	SCW-V2[a] data output		
							Mean movement duration (hours/day)	Days of absence from treatment	Mean number of movements per day
Experimental group	HHK	9	Male	Right	III	Mod.	1.3	2	314
	LHY	17	Female	Left	I	Nor.	4.96	0	2824
	WTK	16	Female	Right	II	Nor.	4.67	0	2411
	CSH	12	Male	Right	III	Mild	2.2	1	1295
	CHY	8	Female	Left	II	Nor.	4.82	0	2833
	FLL	6	Female	Right	II	Mod.	1.2	1	315
Waitlist group	SKH	13	Male	Right	III	Mild	1.3	1	338
	WKS	18	Female	Left	II	Nor.	3.9	0	2187
	AKW	18	Male	Right	II	Nor.	5.9	0	3347
	CWH	8	Male	Right	III	Mod.	0.52	2	259
	CKW	14	Male	Right	I	Nor.	1.1	1	350
	LKC	18	Male	Left	II	Mild	0.7	2	279

SCW-V2[a], sensory cueing wristwatch-version2; Hemi, hemiplegic; IQ, intelligence quotient; yrs, years; MACS, Manual Ability Classification System; Nor., normal, Mod., moderate.

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Table 3. Demographic and medical characteristics of the sample

	Whole sample (n=12)	Experimental group (n=6)	Waitlist group (n=6)	Demographics comparison between two groups (*p* value)[a]
Age (years)	13.08 (4.44)	11.33 (4.46)	14.83 (4.02)	.125
Gender				
Male	7 (58.3%)	2 (33.3%)	5 (83.3%)	.093
Female	5 (41.7%)	4 (66.7%)	1 (16.7%)	
Hemiplegic side				
Right	8 (66.7%)	4 (66.7%)	4 (66.7%)	.999
Left	4 (33.3%)	2 (33.3%)	2 (33.3%)	
IQ				
Normal	6 (50.0%)	3 (50.0%)	3 (50.0%)	.999
Mild	3 (25.0%)	1 (16.7%)	2 (33.3%)	
Moderate	3 (25.0%)	2 (33.3%)	1 (16.7%)	
MACS level				
III	2 (16.7%)	1 (16.7%)	1 (16.7%)	.999
II	6 (50.0%)	3 (50.0%)	3 (50.0%)	
III	4 (33.3%)	2 (33.3%)	2 (33.3%)	
SCW-V2 data output				
Mean movement duration (hours/day)	2.71 (1.97)	3.19 (1.82)	2.23 (2.18)	.229
Days of absence from treatment	0.83 (0.83)	0.67 (0.82)	1.00 (0.89)	.495
Mean number of movements/day	1396 (1231)	1665 (1187)	1127 (1323)	.423

SCW-V2, sensory cueing wristwatch-2nd version; Hemi., hemiplegic; IQ, intelligence quotient; MACS, Manual Ability Classification System; UL, upper limb; pro./sup., pronation/supination; F/E, flex/extension; Nor., normal, Mod., moderate; n, number

a, Chi-Square or paired *t*-tests

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Table 4. Mean (SD) scores of UL efficiency, functional hand use, and arm impairment level at each measurement occasions

Variables	Baselines for two groups (n=12)		Carry-over effect between baselines and end of washout by group of order (n=12)				Treatments effect in the whole sample (n=24)			
			Experimental group (n=6)		Waitlist group (n=6)		Sensory Cueing Treatment (SCT; n=12)		Sham Treatment (n=12)	
	Experimental group (n=6)	Waitlist group (n=6)	Baseline	Start of Sham Treatment	Baseline	Start of SCT	Start of SCT	End of SCT	Start of Sham treatment	End of Sham treatment
BOT-II subtest 3	2.25±1.405	2.33±1.63	2.25±1.41	2.33±1.21	2.33±1.63	2.58±1.86	2.37±1.42	2.54±1.61	2.33±1.3	2.42±1.41
CFUS-quantity	28.27±7.81	27.43±10.7	28.27±7.81	32.6±4.13	27.43±10.7	27.37±10.7	27.82±8.14	32.17±8.11	30.02±8.19	30.93±8.06
CFUS-quality	27.47±7.12	26.53±10.65	27.47±7.12	30.75±4.0	26.53±10.65	25.88±9.32	26.67±7.94	29.25±7.76	28.64±7.98	29.67±7.44
Power grip strength	5.17±4.49	4.97±2.8	5.17±4.49	4.65±3.67	4.97±2.8	5.17±2.8	5.17±3.57	5.39±3.52	4.80±3.12	4.83±3.07
Key pinch strength	1.62±1.46	1.52±1.72	1.62±1.46	1.78±1.32	1.52±1.72	1.3±1.39	1.96±1.40	2.02±1.37	2.15±1.51	2.16±1.52
Three-jaw pinch strength	0.37±0.28	0.52±0.35	0.37±0.28	0.40±0.28	0.52±0.35	0.83±0.69	0.60±0.55	0.62±0.54	0.45±0.31	0.46±0.31
AROM-Wrist flex.	60±28.81	62±13.42	60±28.81	57.83±27.97	62±13.42	56.67±14.38	59.00±20.48	59.33±20.45	59.92±21.03	60.58±20.62
AROM-Wrist ext.	34.33±20.29	31.67±18.62	34.33±20.29	35±17.62	31.67±18.62	30±19.24	32.17±18.98	35.83±18.93	33.33±17.36	35.17±16.30
AROM-Forearm sup.	56.83±31.85	53.33±34.45	56.83±31.85	54.17±32.93	53.33±34.45	52.5±32.21	55.67±30.63	56.67±29.34	53.75±32.13	54.08±31.16
AROM-Forearm pro.	68.33±25.03	70.83±21.55	68.33±25.03	65.83±24.58	70.83±21.55	70.17±20.1	69.25±21.03	69.42±20.53	68.0±22.36	67.58±20.65
AROM-Elbow flex.	135±8.37	130±16.73	135±8.37	138.33±4.08	130±16.73	129.17±13.6	130.9±10.78	132.58±9.44	132.92±12.15	134.17±9.73
AROM-Shoulder flex.	133.33±15.1	135±17.61	133.33±15.1	136.67±17.22	135±17.61	134.17±13.2	133.75±13.5	141.25±15.4	135.83±16.63	135.67±15.52

SCT, sensory cueing treatment; BOT-II subtest 3, Subtest 3 of the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.); CFUS, Caregiver Functional Use Survey; AROM, active Range of Motion; flex., flexion; ext., extension; sup., supination; pro., pronation

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Table 5. Carry-over effect and treatment effect

Variables	Baseline comparison between experimental and waitlist groups (n=12)		Carry-over effect Mean [95% CI] of the difference between baseline and end of washout by group of order (n=12) [b]		Treatment effect Mean changes (±1SD) by two treatments in the whole sample (n=24)				
	Mean difference	*P*-Value [a]	Experimental group	Waitlist group	SCT	*P*-Value[c]	Sham Treatment	*P*-Value[c]	*P*-Value[d]
BOT-II subtest 3	-.083	.926	-.08 [-1.91, 1.75]	-.25 [-.97, .47]	-.17±.615	.368	-.08±.73	.701	.500
CFUS-quantity	.833	.881	-4.33 [-10.12, 1.44]	.07 [-3.45, 3.58]	-4.35±2.08	.000*	-.92±4.44	.489	.028*
CFUS-quality	.933	.862	-3.28 [-9.02,2.45]	.65 [-2.43, 3.73]	-2.575±2.08	.001*	-1.025±4.39	.436	.286
Power grip strength	.200	.928	.52 [-.455, 1.49]	-.20 [-.95, .55]	-.225±.475	.129	-.02±.18	.654	.193
Key pinch strength	-.900	.351	-.17 [-1.18, .85]	.22 [-.535, .97]	-.06±.106	.072	-.01±.12	.780	.286
Three-jaw pinch strength	-.150	.432	.03 [-.16, .09]	-3.17 [-.71, .08]	-.03±.085	.26	-.003±.08	.891	.459
AROM-Wrist flex.	-2.000	.882	2.17 [-5.56, 9.89]	5.33 [-1.36, 12.03]	-.33±5.40	.835	-.67±5.19	.665	.116
AROM-Wrist ext.	2.667	.817	-.67 [-4.22, 2.89]	1.67 [-2.62, 5.95]	-3.67±2.10	.000*	-1.83±4.41	.177	.207
AROM-Forearm sup.	3.500	.859	2.67 [-.82, 6.16]	.83 [-6.14, 7.81]	-1.58±3.06	.103	-.33±2.81	.689	.129
AROM-Forearm pro.	-2.500	.857	2.50 [-1.89, 6.89]	.67 [-12.96, 14.30]	-.667±2.67	.809	.417±4.08	.730	.796
AROM-Elbow flex.	5.000	.533	-3.33 [-11.90, 5.235]	.83 [-8.79, 10.46]	-1.67±3.26	.104	-1.25±4.33	.339	.125
AROM-Shoulder flex.	-1.667	.864	-3.33 [-7.62, .95]	.83 [-8.20, 9.87]	-7.08±5.82	.002*	-.17±7.47	.940	.012*

a, Independent *t*-test comparing baseline difference between experimental and waitlist groups; b, Paired *t*-test analyzing carry-over effect by group of order;

c, Paired *t*-test comparing pre- and post- treatments' means in combined sample; d, Independent *t*-test comparing the mean changes between groups in total sample.

CI, confidence interval; SD, standard deviation; SCT, sensory cueing treatment; BOT-II subtest 3, Subtest 3 of the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.); CFUS, Caregiver Functional Use Survey; AROM, active Range of Motion; flex., flexion; ext., extension; sup., supination; pro., pronation

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