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Original article

Ready! Set? Let's Train!: Feasibility of an intensive attention training program and its beneficial effect after childhood traumatic brain injury

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ABSTRACT

Background: Attention deficits are common after pediatric Traumatic Brain Injury (TBI); they complicate return to activities of daily living and disrupt socioacademic reintegration. Yet, clinicians in rehabilitation settings have limited access to cognitive remediation protocols for which feasibility has been demonstrated.
Objective: The aim of this study was to evaluate the feasibility of intensive attention process training program Ready! Set? Let's Train! (RST), based on an adaptation of the Attention Process Training-I program.
Materials and methods: In a randomized controlled trial, participants with attention deficits were assigned to receive the attention process training intervention (RST) or Homework Assistance (HWA). Pre- and post-intervention assessments consisted of standardized attentional and executive tests and a behavior checklist.
Results: Analyses conducted for 17 participants (RST, $n = 8$; HWA, $n = 9$; mean age 14.70 $\pm$ 2.17 years, 11 males) indicated the study was successful in that it showed improvements in working memory ($F(14) = 5.44$, $P = 0.04$; $\eta^2 = 0.19$), inhibition ($F(14) = 10.18$, $P = 0.007$; $\eta^2 = 0.75$) and cognitive flexibility ($F(14) = 5.36$, $P = 0.04$; $\eta^2 = 0.57$).
Conclusions: These findings indicate positive support for combined process-specific and metacognitive strategy training for attention and executive functions.

1. Introduction

Attentional impairments are among the most pervasive consequences of pediatric Traumatic Brain Injury (TBI) with evidence of quasi-systematic deficits across selective, divided, and sustained attention [1]. Childhood TBI also affects executive functioning, which results in impairments in inhibition [2], cognitive flexibility [3], planning [4], working memory [5] and metacognition [6].

Although attentional and executive problems can persist in the long-term [7], cognitive remediation, a type of rehabilitation treatment aimed at improving cognitive functioning, appears to limit or counter the negative impact of childhood TBI [8]. For example, van't Hooft et al. [9] examined the effectiveness of an attention and memory training program (Amat-c) in children with brain injury aged 9 to 16 years and found improved sustained and selective attention in the intervention group as compared to a control group that received adult interaction and support. Similarly, Galbiati et al. [10] examined the impact of a computerized attention remediation program (RehaCom) in children 6 to 18 years with TBI (45 min, 4 times a week for 6 months) and found greater improvement in inhibition, sustained and selective attention in the intervention group than children who did not complete the program. One of the limitations of these intervention programs is that they were designed to last between 17 and 40 weeks. Although these lengthy programs may be efficient in the context of severe brain injuries, they have limited feasibility and are often unrealistic in clinical settings, where services need to be economical and efficient.

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The Attention Process Training-I (APT-I) program appears to have considerable utility in addressing attentional deficits after TBI. Based on Sohlberg and Mateer's [11] theoretical model, the APT-I includes visual and auditory exercises targeting 5 attentional components (focalized, sustained, selective, alternating, divided). Positive results for attention have been documented in adults with TBI, as well as transfer effects to memory and activities of daily living [12], which suggests extensive beneficial effects of the program. An adaptation of the APT (Pay Attention!) [13], designed for children 4 to 10 years old, showed improvements for sustained, selective and alternating attention in children with attentional deficits related to fetal alcohol syndrome [14] and in fluid reasoning, cognitive flexibility and working memory in children with Attention-Deficit/Hyperactivity Disorder (ADHD) [15]. However, currently available APT training methods have no predefined program structure and are typically designed to last between 17 and 40 weeks. These characteristics imply time-consuming planning by clinicians for each session and the overall program. In addition, no APT program exists for individuals between age 10 and 17 years. A further constraint of previous work is that most cognitive rehabilitation approaches tend to be based on attention-specific approaches, omitting metacognitive strategies.

To address these limitations, we developed the Ready! Set? Let's Train! (RST) program [16], an adaptation of the APT-I [17], for youth between age 10 and 17 years, with specific inclusion of a metacognition component. The RST program [16] is based on Sohlberg and Mateer's [17] model but has a predefined, structured program, which involves training each attentional process by using a specific number of tasks within the same session. To improve understanding of the bases of each attentional exercise and to increase motivation for the training program, lay descriptions of each attention component are included in the protocol. To improve awareness of attentional difficulties and control over cognitive and behavioral functioning, feedback and self-evaluation of performances are reviewed with the participant after each task in order to develop effective metacognition. Developmental research suggests a link between the self-regulation aspect of metacognition (e.g., monitoring and control) and the development of executive functions [18]. Limited attention has been paid to the evolution of metacognition during adolescence. However, in one study, adolescents (aged 13–15 years) and adults evaluated their performance on propositional, spatial and social reasoning tasks, and self-evaluation was shown to improve between adolescence and adulthood [19].

Metacognition includes 3 theoretical components: knowledge, experience and metacognitive strategies [20]. The development of metacognitive strategies, such as slowing down responses to preserve a high level of accuracy, enhances executive functions such as inhibition [21]. For example, knowing how to slow down is particularly important for facilitating inhibition, whereas detecting errors and considering alternative responses is thought to be important for emphasizing shifting [22]. In the RST program, the 3 metacognitive components (knowledge, experience and metacognitive strategies) are reunited to allow for optimal control over attentional processes and other cognitive processes such as memory and executive functions.

Demonstrating feasibility of an intensive attention remediation program that includes metacognition has obvious benefits for prognosis after pediatric TBI and may also facilitate clinical work in rehabilitation settings. According to Sohlberg et al. [12], attention process training refers to a deliberate effort to administer a therapeutic program that improves a wide range of tasks involving attention. Thus, the aim of this study was to evaluate whether an intensive structured attention process-training program, the RST [16], is feasible in a clinical setting and is more effective than Homework Assistance (HWA). We expected improvements in (1) attentional functioning, such as in vigilance, sustained, selective, alternating and/or divided attention; and (2) generalization to memory (verbal/auditory) and executive functioning (working memory, inhibition, goal planning and/or flexibility) because attentional functions are implicated in these processes.

2. Material and methods

2.1. Participants and setting

We used an exploratory approach because of sample size restrictions. The study was approved by the local ethics committee and all participants provided written consent for participation. We recruited children and adolescents with TBI who were consecutively admitted to a Quebec rehabilitation center between June 2012 and September 2013. Inclusion criteria were:

1) age 10.0 to 17.0 years;
2) documented evidence of TBI sufficiently detailed to determine injury severity;
3) chronic phase (time since injury between 3 months and 6.0 years);
4) IQ $\geq$ 80;
5) French-speaking;
6) attending an academic institution;
7) complaints of new or increased attentional deficits since the TBI, by the participant or the parent during the medical history performed by a neuropsychologist.

Exclusion criteria were (1) evidence of pre-existing physical, neurological, psychiatric or developmental disorder other than ADHD and (2) medication known to affect cognitive functioning, other than psychostimulants. ADHD presence was not excluded mainly because it represents an important proportion of the pediatric TBI population [23]. Thus, its exclusion would have biased the sample and limited the recruitment.

Children were divided into intervention and control groups by simple randomization or covariate-adaptive randomization because recruitment was conducted in 2 phases (see Figs. 1 and 2). The intervention group received the attention-training program RST [16] and the control group received HWA. We used an active control group to control for the effects of fixed and constant sessions with the presence of a therapist, a factor known to create placebo type improvements [24] and to control for test-retest effects.

2.2. Procedure

Before and after the intervention, participants were assessed on a cognitive battery including attentional, and executive measures (see Fig. 1). No repeated baseline measures were performed before the intervention. The mean delay between the pre-intervention assessments and the intervention was 99 and 35 days for the RST and HWA groups and mean delay between the end of the intervention and post-intervention assessments was 3 and 9 days, respectively. The assessment was divided into 2 (ages 12–17 years) or 3 sessions (ages 10–11 years) with breaks as needed. The order of the tests was counterbalanced between participants and pre- and post-assessment. The blind post-intervention assessments were performed by 3 graduate students who received formal psychometric training.

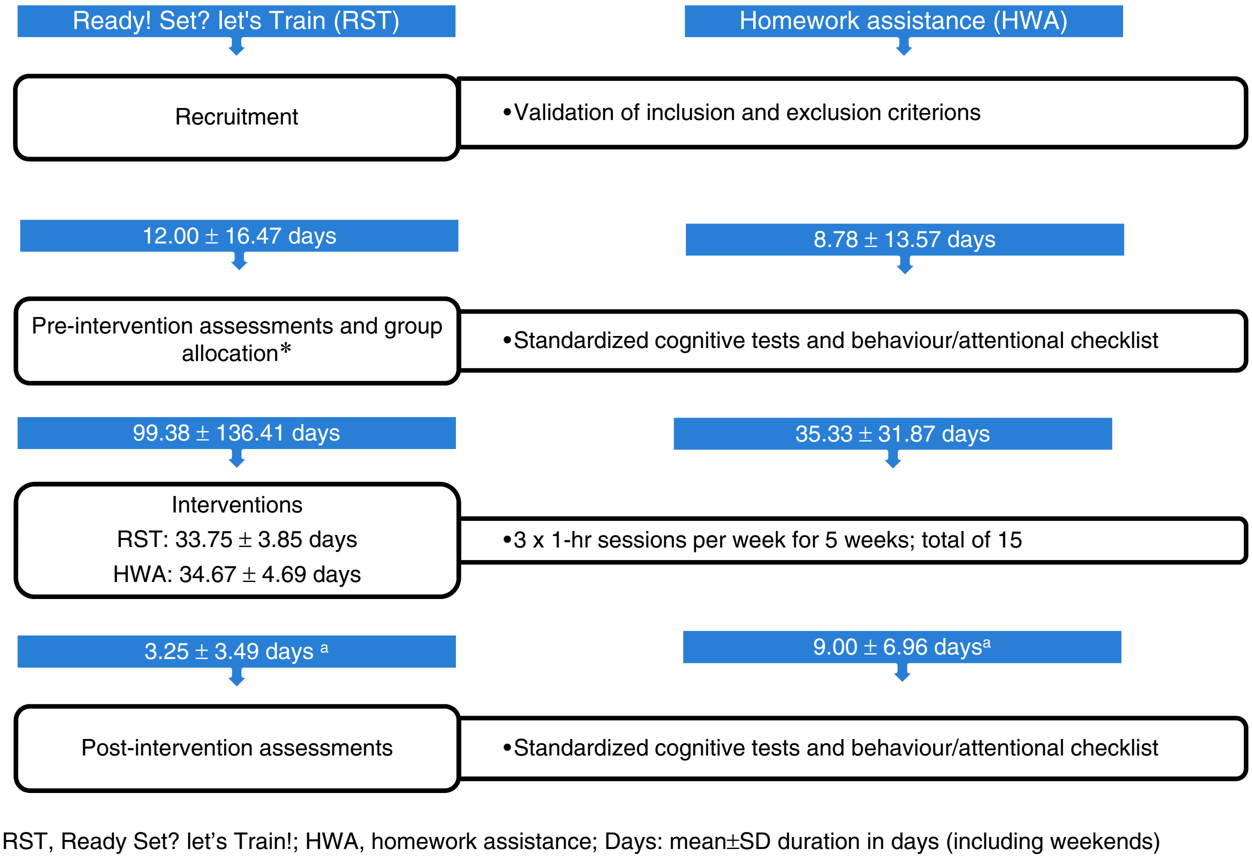

Fig. 1. Flow of the study (CONSORT guidelines).

2.3. Intervention

2.3.1. Ready! Set? Let's Train! (RST)

The experimental group received 15 training sessions at school during class or lunchtime at the rate of 3 one-hour sessions per week. The training sessions took place in a closed room with limited distractions. When the intervention could not be performed in the school setting, training sessions were provided at home under similar conditions. The frequency of intervention was chosen to ensure optimal intervention intensity [25]. In the RST program [16], the attentional components included in Sohlberg and Mateer's model [17] are remediated by using predetermined visual and auditory modality tasks detailed in a standardized clinician/trainer protocol. The visual tasks consist mainly of paper-and-pencil activities with or without visual distractors such as cancellation-visual search or alternating simple tasks such as additions and subtractions. Auditory tasks consist of letters, numbers or words presented with or without interference (e.g., man reading the news). In general, the duration of each single exercise varies from 3 to 5 min.

The RST program [16] includes a metacognitive component targeting knowledge, experience and strategies. Metacognitive knowledge consisted of identifying which type of attention was solicited during the task and which strategy to use to optimize performance, and associations were made with everyday situations. Metacognitive experience was addressed via performance feedback from the examiner and self-evaluation of performance. Specifically, after each attentional task, an immediate retroaction was given in which errors and response times were reviewed with the participant. Metacognitive strategies consisted of monitoring and regulating cognitive processes by using anticipation, planning and verification. The 5 cognitive strategies ("Right-Left Detective": visual scanning/vigilance; "Psst!": sustained attention; "Wait a minute!": impulsivity; "Focus": selective attention; and "Not 2": divided attention) were taught during the program and were presented via pictograms visible during the entire session. Finally, in addition to concrete strategies, the program includes examples of daily living activities adapted for children and adolescents to facilitate the generalization of potential attentional improvements (see Supplemental material).

2.3.2. Homework assistance (HWA)

The setting, frequency, duration and number of sessions were identical for the HWA control group and RST intervention (i.e., 3 one-hour sessions/week for 5 weeks). If the HWA could not be administered in the school setting for any reason, it was provided at home in a closed room with limited distractions. Attentional training was replaced by HWA consisting of everyday academic demands. When the participant brought no homework to the session, targeted schoolwork exercises sourced from interactive academic websites were completed by the participants. No specific attentional or clinical aspects were targeted during these sessions (e.g., TBI, attentional problems and strategies).

2.4. Measures

2.4.1. Socioeconomic status

Participants' family socioeconomic status was calculated by using the Blishen Socioeconomic Index (1981) for descriptive purposes [26]. For participants from double wage-earner families, the highest socioeconomic score was used.

2.4.2. Medical information

TBI severity, acute Glasgow Coma Scale (GCS), duration of loss of consciousness (LOC), duration of post-traumatic Amnesia (PTA),

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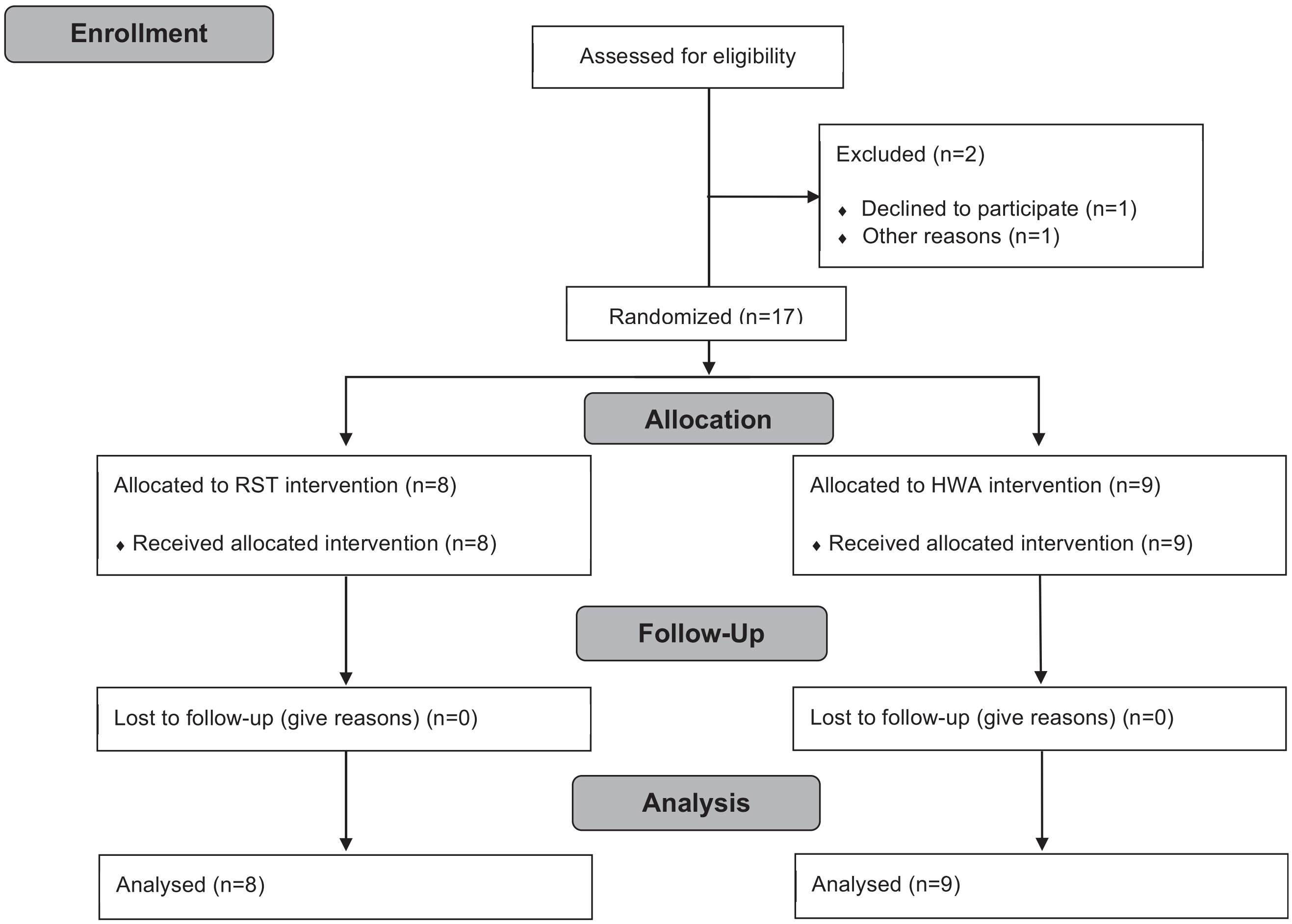

RST, Ready! Set? let's Train!; HWA, homework assistance

Fig. 2. Flow of participants in the study (CONSORT guidelines).

number of neurological signs and symptoms, clinical neuroimaging results and duration of medication induced coma and/or neurosurgical intervention, were obtained from participant medical files completed by the treating doctor (see Tables 1 and 2).

2.4.3. Intellectual ability

(Wechsler Abbreviated Scale of Intelligence [WASI]) [27]: For descriptive purposes, an estimate of full scale Intelligence Quotient (IQ) was calculated by using 2 subtests (vocabulary, matrix reasoning) with mean 100 $\pm$ 15.

2.4.4. Attention

The following attention measures were administered pre- and post-intervention to document performance in 5 attentional domains. Whenever possible, subtests from the computerized Test of Attentional Performance (TAP) [28] were used. Unless otherwise stated, the dependant variables were the total number of errors for each test.

A. Vigilance (TAP-Alertness) [28]: reaction time was measured by button press in response to a critical stimulus appearing on the computer monitor, preceded by a cue stimulus presented as a warning tone.

B. Sustained Attention (VIGIL Continuous Performance Test) [29]: in the "K" condition, participants press a button each time the letter K (144) appears but not when other, randomly presented letters (336) are sequentially presented.

C. Selective attention (TAP-Visual scanning) [28]: participants respond by button press to detect whether a matrix of 5 $\times$ 5 symbols includes a critical stimulus or not (100 items).

D. Attentional shifting (TAP-Flexibility) [28]: participants respond by button press according to whether the target stimulus (letter or number) appears to the left or the right of the monitor (70 items).

E. Divided attention (TAP-Divided attention) [28]: a varying number of crosses appear simultaneously on the screen. When the crosses form a square, participants press the reaction key as quickly as possible (14 items). Simultaneously, high and low auditory tones are presented in sequence. Participants press the reaction key if the same tone (i.e., high-high, low-low) occurs twice in a row (16 items).

F. Inattention (IN) and Hyperactivity-Impulsivity (HI) symptoms (Conners Rating Scale) [30]: participants completed this self-reporting questionnaire to assess symptoms of inattention (IN) and hyperactivity-impulsivity (HI) before and within 14 days after the end of the intervention (99 items). The total number of IN symptoms (maximum 9 symptoms) and the HI index (maximum 9 symptoms) are reported.

2.4.5. Memory

The following memory measures were administered pre- and post-intervention to test the generalization of findings in attention-related cognitive domains.

Table 1
Demographic, injury characteristics and details of medication for participating groups.

	RST	HWA	η^2
Demographics			
Sex (% female)	8 (12.5)	9 (44.4)	0.45
Age at intervention, mean ± SD	14.8 ± 2.3	14.7 ± 0.5	0.001
IQ, mean ± SD	106.38 ± 12.02	103.44 ± 10.71	0.02
Socioeconomic status, mean ± SD	49.42 ± 7.85	49.80 ± 16.33	0.03
Injury characteristics			
Age at injury, mean ± SD	12.68 ± 3.73	13.52 ± 2.92	0.02
Time since injury, mean ± SD	2.15 ± 2.16	1.22 ± 1.45	0.07
Mild TBI	5 (29.40)	5 (29.40)	
Moderate TBI	2 (17.60)	3 (11.80)	0.09
Severe TBI	1 (5.90)	1 (5.90)	
Acute GCS, mean ± SD	11.13 ± 5.19	11.38 ± 3.70	0.001
Loss of consciousness	4 (50)	2 (22)	
Post-traumatic amnesia	4 (50)	4 (44)	
Abnormal CT/MRI	4 (44)	5 (63)	
Neurosurgical intervention	1 (13)	0 (0)	
Coma < 1 day (medication)	1 (13)	1 (11)	
Treatment			
Citalopram (Cipralex; 10 mg/day)		1 (13)	
Methylphenidate (Concerta; 28 mg/day)	2 (22)		
Lisdexamfetamine (Vyvanse; 20 mg/day)	1 (13)		
Atomoxetine (Strattera; 25 mg/day)			
Acetaminophen-codeine (Ratio-Emtec-30; 300 mg/PRN)	1 (13)		

Data are *n* (%) unless indicated; η^2: effect size for group mean differences; age and time since injury in years; IQ: Intelligence Quotient; RST, Ready! Set? let's Train! Attention Training Program; HWA: Homework Assistance; TBI: Traumatic Brain Injury; GCS: Glasgow Coma Scale; PRN: *Pro Re Nata* (only if needed).

Table 2
Injury characteristics for RST and HWA groups.

Participants	Severity	Causes	Acute GCS	Neurological signs	Hospitalisation	Time since injury	Acute brain scans
RST							
1	Mild	Fall	15	4	< 1	351	Normal
2	Mild	Hit	15	3	< 1	125	Normal
3	Moderate	Fall	11	4	5	753	Right temporal fracture and contusion; epidural hematoma
4	Mild	Hit	15	0	< 1	566	Normal
5	Moderate	Fall/RTA	3	0	5	2162	Left occipital skull fracture extending to posterior foramen
6	Mild	Hit	14	3	< 1	98	Small left sylvian sub-arachnoid hemorrhage; displaced right parietal fracture; basal skull fracture
7	Mild	Fall	13	5	4	486	Undisplaced left parietal skull fracture with parieto-temporal petechial contusions and oedema; subdural blood collections
8	Severe	RTA	3	N/A	21	1887	Left temporal oedema with mass effect and associated petechial hemorrhage; cerebellar oedema; small subdural hemorrhage at the level of the foramen magnum and tentorium; multiples cranial and facial fractures
HWA							
9	Mild	Fall	15	5	< 1	115	Normal
10	Moderate	Fall	11	3	7	1126	Longitudinal fracture of occiput and oedema
11	Moderate	Fall	9	4	4	1520	Right panetal linear skull fracture, right sub-dural hematoma and frontal-parietal microhemorrhages
12	Mild	Fall	N/A	7	< 1	91	N/A
13	Mild	Hit + fall	13	4	10	352	Normal
14	Mild	Hit	15	2	< 1	141	Normal
15	Mild	Hit + Fall	15	3	< 1	106	N/A
16	Severe	RTA	6	0	16	77	Diffuse cerebral oedema with sulcal effacement
17	Moderate	RTA	7 (13)	2	15	204	MRI: frontal and temporal contusions and diffuse axonal injury

GCS, Glasgow Coma Scale; Hospitalization and time since injury = in days; Time since injury = delay between injury and pre-intervention assessments; RTA, Road Traffic Accident; RST, Ready! Set? let's Train! Attention Training Program; HWA, Homework Assistance; N/A; Not Available. Neurological signs included: physical symptoms: blurry vision, dizziness, double vision, fatigue, headache, light sensitivity, nausea, noise sensitivity, sleep disturbance; cognitive symptoms: forgetfulness, poor concentration, taking longer to think; Emotional symptoms: depression, frustration, irritability, restlessness. Participant 17: fluctuating GCS due to intubation.

A. Visual memory (Brief Visuospatial Memory Test-Revised [BVMT-R]) [31]: in 3 learning trials, the participant views a page of 6 geometrical figures for 10 s and is asked to draw as many as possible in their correct location. Delayed recall is tested after 25 min. The raw scores for the delayed recall (maximum score 12) are reported.

B. Verbal memory (Rey-Taylor Auditory-Verbal Learning Test [RAVLT]) [32]: a 15-noun list (list A) is read aloud for 5 consecutive trials. Each trial is followed by a free recall test. The order of presentation of words remains fixed across trials. On completion of trial 5, an interference list of 15 words (list B) is presented, followed by a free recall test of that list. Immediately after this, delayed recall of the first list is tested (trial 6) without further presentation of those words. After a 20 minutes delay, the examinee is again required to recall and recognize words from list A (trial 7). The raw scores for the total delayed recall (maximum score 15) are reported.

2.4.6. Executive functioning

The following executive function measures were administered pre- and post-intervention to test the generalization of findings in attention-related cognitive domains.

A. Working memory (TAP) [28]: participants are required to determine whether each number presented in sequence on the monitor is the same as the previous number (condition 1) or the second-to-last number (condition 2). The raw score total number of errors is reported.

B. Inhibition (Delis-Kaplan Executive Function System [DKEFS]: Color-Word Interference-Inhibition) [33]: participants are asked to correctly name or read 50 colours or words as quickly as possible. In the inhibition condition, they must name the incongruent ink colour in which 50 colour words are printed. The raw score for completion time is reported.

C. Cognitive flexibility (DKEFS: Color-Word Interference-Inhibition/Switching) [33]: for 50 colour words, participants are asked to name the incongruent ink colour or to read the word when a colour word is surrounded by a black rectangle. The raw score for completion time is reported.

D. Goal planning (adapted Tower of London [TOL]) [34]: participants must rearrange beads in a fixed number of moves on vertical rods to match a model (15 items of increasing complexity). Three points are awarded for each item completed on the first trial (2 points for second trial and 1 point for third trial). The raw score for the total items is reported (maximum score 45).

2.5. Statistical analyses

Exploratory analyses were performed given the modest sample size. To ensure blinding between the intervention providers and those conducting the statistical analyses, participants were identified by a code. Analyses involved Student *t* test for age at injury and intervention (years), intellectual functioning (WASI), socioeconomic status (Blishen), time since injury (years), acute GCS and compliance to the intervention (days). Chi-square analyses were used to determine any differences in data by sex or TBI severity. Data are reported as number (%) or mean ± SD. Overall group differences were analyzed by analysis of covariance, the baseline score on the measure of interest being a covariate, which allowed for assessing residualized change over time. The dependant variables were vigilance (TAP), sustained attention (VIGIL), selective attention (TAP), attentional shifting (TAP), divided attention (TAP), visual memory (BVMT-R), verbal memory (RAVLT), working memory (TAP), inhibition (DKEFS), cognitive flexibility (DKEFS), goal planning (TOL), and behavioral measures (Conners). Post-hoc paired *t* tests were used to examine the magnitude of effects in each group. Effect Sizes (ES) are reported by a partial η^2 (small effect ≤ 0.01, moderate effect = 0.06, large effect ≥ 0.14 [35]). We did not correct for multiple comparisons because of the exploratory nature of the analyses. $P < 0.05$ was considered statistically significant. All data were analyzed by using SPSS 20 (SPSS, Inc., Chicago, IL).

3. Results

3.1. Sample description

Among the 19 participants with TBI who were initially recruited, 2 participants withdrew before completing the study (Fig. 2) (RST, *n* = 8; HWA, *n* = 9; mean age 14.70 ± 2.17 years, 11 males). Participant characteristics are presented in Tables 1 and 2. Baseline functioning is reported for all measures before the intervention (Table 3). The RST and HWA groups showed no significant difference for sex ($\chi 2$ (1, *n* = 17) = 1.81, *P* = 0.064; Φ = 0.45), age at injury (t(15) = 0.52, *P* = 0.608; $\eta 2$ = 0.02), age at intervention (t(15) = −0.12, *P* = 0.907; $\eta 2$ = 0.001), TBI severity ($\chi 2$ (2, *n* = 17) = 0.14, *P* = 0.93; Cramer's V = 0.09), time since injury (t(15) = −1.01, P = 0.330; $\eta 2$ = 0.07), IQ (t(15) = −0.53, *P* = 0.603; $\eta 2$ = 0.02), socioeconomic status (t(11.79) = 0.06, *P* = 0.950; $\eta 2$ = 0.03) or acute GCS score (t(14) = 0.11, *P* = 0.913; $\eta 2$ = 0.001), nor did they differ in terms of compliance and participation, represented by the total number of experimental (14.88 ± 0.35) and control (14.88 ± 0.33) sessions.

3.2. Measures of attention

The RST group was compared to the HWA group on all measures of attention to explore pre-intervention differences and possible improvements related to the RST intervention. We found significant group differences for divided attention before the intervention, for visual (F(14) = 18.41, *P* = 0.001; η^2 = 0.58) and auditory (F(14) = 9.21, *P* =0.009; η^2 = 0.40) tasks (Table 3). Before the intervention, the RST group made significantly fewer errors than the HWA group on the divided attention-visual and -auditory tasks (visual: mean 2.00 ± 1.31 vs 3.67 ± 2.29; auditory: mean 1.00 ± 1.07 vs 2.78 ± 2.33). We found significant group differences for number of self-reported inattention symptoms (F(13) = 5.18, *P* = 0.04; η^2 = 0.34). Before the intervention, the RST group reported significantly more symptoms than the HWA group (3.88 ± 2.53 vs

Table 3
Results for all measures of attention, memory and executive functioning.

ANCOVA						
	Before intervention		After intervention		F	Partial η^2
	RST	HWA	RST	HWA		
Vigilance$_{\text{-errors}}$	1.25 ± 1.04	1.56 ± 0.73	1.38 ± 0.52	1.44 ± 0.88	$0.01_{\lvert 1,14 \rvert}$	0.13
Sustained attention$_{\text{-errors}}$	7.25 ± 7.32	21.22 ± 20.78	2.75 ± 2.82	11.22 ± 7.66	$4.32_{\lvert 1,14 \rvert}$	0.45
Selective attention$_{\text{-errors}}$	10.75 ± 4.23	13.75 ± 6.16	5.38 ± 2.88	9.13 ± 6.20	$1,25_{\lvert 1,12 \rvert}$	0.06
Attentional shifting$_{\text{-errors}}$	9.88 ± 5.22	8.25 ± 4.59	6.00 ± 2.39	7.33 ± 4.00	$0.26_{\lvert 1,13 \rvert}$	0.06
Divided attention–visual task$_{\text{-errors}}$	2.00 ± 1.31	3.67 ± 2.29	2.13 ± 2.17	2.78 ± 1.79	$0.82_{\lvert 1,14 \rvert}$	0.52
Divided attention–auditory task$_{\text{-errors}}$	1.00 ± 1.07	2.78 ± 2.33	1.13 ± 0.99	1.33 ± 1.32	$0.95_{\lvert 1,14 \rvert}$	0.32
Inattention symptoms $_{\text{(max 9)}}$	3.88 ± 2.53	3.44 ± 1.81	2.71 ± 1.70	3.89 ± 2.62	$1.72_{\lvert 1,13 \rvert}$	0.23
Hyperactivity-impulsivity symptoms $_{\text{(max 9)}}$	1.25 ± 1.58	2.67 ± 0.87	0.86 ± 0.69	2.56 ± 1.81	$0.19_{\lvert 1,13 \rvert}$	0.24
Visual memory$_{\text{-total score (max 12)}}$	10.38 ± 1.41	10.00 ± 0.71	10.25 ± 1.67	10.11 ± 1.17	$0.02_{\lvert 1,14 \rvert}$	0.13
Verbal memory$_{\text{-total score (max 15)}}$	14.63 ± 0.74	14.44 ± 0.88	14.50 ± 0.53	13.89 ± 1.36	$1.62_{\lvert 1,14 \rvert}$	0.01
Working memory$_{\text{-total errors}}$	2.13 ± 2.10	2.33 ± 1.73	0.38 ± 0.74	2.44 ± 2.30	$5.44_{\lvert 1,14 \rvert}$	0.19*
Inhibition$_{\text{-completion time (s)}}$	53.13 ± 11.58	60.33 ± 12.00	41.50 ± 7.31	58.44 ± 13.89	$10.18_{\lvert 1,14 \rvert}$	0.75**
Cognitive flexibility$_{\text{-completion time (s)}}$	60.75 ± 12.87	64.11 ± 10.74	50.34 ± 8.90	61.89 ± 12.83	$5.36_{\lvert 1,14 \rvert}$	0.57*
Goal planning$_{\text{-total score (max 45)}}$	36.63 ± 4.87	33.11 ± 4.14	40.38 ± 2.62	37.22 ± 3.46	$4.05_{\lvert 1,14 \rvert}$	0.12

RST: Ready! Set? let's Train! Attention Training Program; HWA: Homework Assistance; ANCOVA, Analysis of Covariance; ||: degrees of freedom.
* $P < 0.05$.
** $P < 0.01$.

3.44 ± 1.81). Large ES values were found for these comparisons. We used analysis of covariance, controlling for baseline symptom levels on the attention measure, to test whether the RST program was associated with greater improvements in attention functions than HWA. The RST and HWA groups did not differ on any of the attention outcomes in the sample as a whole (Table 3). Large non-significant ES values were found for measures of sustained (η^2 = 0.40) and divided attention (visual task; η^2 = 0.40).

3.3. Measures of memory and executive functioning

Before the intervention, we found large significant group differences in executive function measures for the inhibition task (η^2 = 0.58) and the cognitive flexibility task (η^2 = 0.62) (Table 3); the RST group was significantly faster than the HWA group on the inhibition task (53.13 ± 11.58 vs 60.33 ± 12.00 s) and the cognitive flexibility task (60.75 ± 12.87 vs 64.11 ± 10.74).

Participants receiving the RST had significantly better performance on measures of working memory (η^2 = 0.19), inhibition (η^2 = 0.75) and cognitive flexibility (η^2 = 0.57) than those receiving the HWA after controlling for baseline symptoms. After the intervention, the RST group made fewer errors than the HWA group on the working memory task (0.38 ± 0.74 vs 2.44 ± 2.30) and was faster than the control group on the cognitive flexibility task (50.34 ± 8.90 vs 61.89 ± 12.83 s) and the inhibition task (41.50 ± 7.31 vs 58.44 ± 13.89 s). Large ES values were found for these comparisons. These findings suggest that the RST program may promote improvements in executive functioning after TBI as compared with HWA.

4. Discussion

We found no training improvements in attentional functions after the RST intervention, even though participants anecdotally reported qualitative improvements in everyday life activities at home and in school. Of note, we found large non-significant effects for measures of sustained and divided attention. These findings may suggest that the differences are sufficiently important to suspect a clinical effect of the intervention, but may have not been detected because of lack of statistical power in our study. This feasibility study was successful in showing participants' compliance and detecting a potential training effect on inhibition, cognitive flexibility and working memory (large ES values). These positive effects on executive functions are consistent with previous intervention studies suggesting that broad-based training, including both process-specific and metacognitive approaches, holds promise for the remediation of cognitive deficits after pediatric TBI [10,36]. Including education, feedback on performance, acknowledgment or awareness of attentional processes in activities of daily living and implementing concrete strategies are assets of the RST training program and the program may have encouraged the development of metacognition with possible indirect effects reflected by improvements in executive functions.

Similar indirect effects were found by Tamm et al. [15] in examining the feasibility and efficacy of Pay Attention! [13], an attention intervention program in children with ADHD. Participants were given immediate feedback regarding their performance, and trainers spent time during each session discussing how the targeted attentional skill could be applied in a home or school setting. This study showed significant improvement in executive function abilities, but had no treatment effects on any other neuropsychological outcomes, including attention. These results support the present findings suggesting that attention training may indirectly impact executive functions, possibly via metacognitive regulation, a hypothesis that could be confirmed in future studies by assessing transfer and generalization of metacognition improvements in daily living activities.

Increasing evidence suggests that cognitive processes that remain impaired in the chronic phase after TBI are mainly related to executive functions, including inhibition and cognitive flexibility [37]. Given that executive functions are an important part of optimal child development and drive academic, behavioral and social competence, the training and rehabilitation of these functions becomes imperative after brain injury. In support of this, Suzman and colleagues [38] found considerable improvement in executive functions with an intervention targeting problem-solving, metacognition and self-regulation.

The lack of significant improvement in tasks of attention may be related to a number of factors. First, subjective complaints of attention problems may not optimally reflect the presence of attentional deficits. Of note, the group averages for number of symptoms of inattention and/or hyperactivity-impulsivity were sub-clinical before the intervention. More significant improvements in attention may be evident in children with TBI who demonstrate clinical levels of attention deficit post-injury. The sub-clinical scores of the participants before the intervention may have limited the range for improvement. In addition, the lack of significant improvement in attention measures may be due to the use of HWA as a control, which constitutes a conservative approach with some advantages and disadvantages. The HWA group may have unintentionally shown improved cognitive functions because taking part in supervised homework sessions may encourage participants to sustain their attention.

4.1. Limitations and conclusions

The data are based on a small and heterogeneous sample of youth with TBI, thus findings may not generalize to the whole pediatric TBI population. However, the sample size is similar to previous intervention work [12]. The scope of the conclusions is also limited by the absence of measures assessing transfer and generalization to everyday life activities, which is an interesting direction for future research. A strength of the study is that it follows the gold standards of cognitive rehabilitation: (1) attention training took place in the chronic phase and included process-specific training and metacognitive strategies [39]; (2) the intensity of training was distributed and sustained and consisted of 30- to 60-min sessions [39]; (3) clinical rehabilitation assessment was complemented by computerized tools for attention (TAP) [40], and (4) education was used to improve cognition and adherence to intervention programs [36]. Metacognitive knowledge was not measured quantitatively, preventing us from drawing conclusions in this regard; the positive effects of the metacognitive training should be assessed in future work. The program could potentially benefit other populations with attentional or executive dysfunctions because it was designed to address and improve general daily cognitive strategies.

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Disclosure of interest

The authors declare that they have no competing interest.

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