

REGULAR ARTICLE

Training of attention and memory deficits in children with acquired brain injury

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Abstract

This pilot study concerns cognitive rehabilitation of children with acquired brain injury (ABI).

Aim: The aim is threefold; to determine (1) whether the Amsterdam Memory and Attention Training for Children (AMAT-C) programme for children with ABI can be integrated in the child's school, (2) whether supervision in the school-setting maintains the child's motivation throughout the training programme and (3) whether positive changes in memory, attention and executive functions are found with this implementation of the training method.

Methods: Seven children with memory and/or attention deficits after ABI were trained with AMAT-C. Measures used were programme evaluation questions, neuropsychological tests and a questionnaire concerning executive functions.

Results: Overall, children, parents and trainers were satisfied with the programme and the children were motivated throughout the programme. The children showed significant improvements in neuropsychological subtests, primarily in tests of learning and memory. No overall change in executive functions was noted.

Conclusion: Provision of AMAT-C training and supervision at the child's school appears to ensure (1) satisfaction with the programme, (2) sustaining of motivation and (3) improvements in learning and memory.

INTRODUCTION

Children with acquired brain injury (ABI) are rarely offered training programmes designed for children focussing specifically on reducing memory as well as attention deficits. This despite the fact that memory deficits are a known ABI sequela, at least for some aetiologies such as traumatic brain injury (1), and that attention deficits are a documented ABI sequela typically affecting selective and sustained attention (2).

Attention and memory deficits in children with ABI are very important issues to address as such deficits reduce the child's ability to acquire essential knowledge, which in turn influences quality of life both from short- and long-term perspectives (3). For example, memory and attention deficits reduce the child's ability to acquire full education thereby jeopardizing job opportunities (4).

Unfortunately, only a few studies exist which focus on developing and evaluating paediatric rehabilitation

methods for children with ABI as well as meeting criteria for evidence-based interventions. For reviews see e.g. (5–7), for level 2 intervention studies [as defined by the *Clinical Practice Guideline Process Manual*(8)] see (9–11).

Several different intervention models targeting ABI sequelae exist and it is debated which model is most effective and cost-efficient in the post-acute phase. The intervention models differ depending on whether focus is on functional adaptation, restorative intervention or a more holistic, context-sensitive approach focussing on quality of life (12). The models also differ regarding locus of intervention, length and intensity. Some take place in centralized, intensive rehabilitation facilities, which are often offered in the post-acute phase (4,11,13), while less intensive rehabilitation facilities may offer services on a weekly or monthly basis (14), potentially throughout childhood. Sohlberg and Mateer state that the primary context for rehabilitation for children with ABI after the acute and sub-acute stages is the school (15).

The focus of this study was to find an intervention method suitable for adaptation into the individual child's school, which included training of memory and attention as well as metacognitive elements.

The purpose of placing intervention in the school-setting was to augment possibilities of transferring trained skills to the child's everyday learning context and to prevent negative social consequences of an intensive training programme that keeps the child from participating in daily school life with peers.

Abbreviations

ABI, acquired brain injury; AMAT-C, Amsterdam Memory and Attention Training for Children; BRIEF, behaviour rating inventory of executive functions; N, number; P, probability; RAVLT, Rey auditory verbal learning test; RCFT, Rey complex figure test and recognition trial; SD, standard deviation; SPSS, Statistical Package for the Social Sciences; TEA-Ch, Test of Everyday Attention for Children; WISC-III, Wechsler Intelligence Scale for Children III.

No standardized intervention to reduce memory- and attention deficits was available in Danish at commencement of the study. A review of the international literature at that time revealed no well-described child-friendly cognitive training methods except for a Dutch method called Amsterdam Memory and Attention Training for Children (AMAT-C) (16).

The theoretical basis of AMAT-C is modelled upon cognitive rehabilitation as described by Sohlberg and Mateer (17). One of the strengths of the AMAT-C is that the method was developed for children rather than being an adaptation of an adult training programme, a common practice in, and a general criticism of traditional paediatric rehabilitation, see e.g. (18). The programme runs for 18–20 weeks (weeks 19–20 are repetition weeks and may thus be left out), during which the child practices different assignments for approximately 45 min per day every weekday. The training takes place on a one-to-one basis. The child is coached by a trainer, who receives weekly supervision from a specialist with expert knowledge on children with cognitive deficits. Several cognitive areas are trained: sustained, focussed and divided attention; strategies for verbal, visual, episodic and semantic memory; and mental tracking. See Figure 1 for an overview of training phases and elements.

The AMAT-C has previously been seen to have a significant effect in a controlled study of children treated for cancer with attention and memory deficits in the Netherlands (Treatment group: $n = 25$, Control group: $n = 19$) (19). In addition to cognitive gains, the Dutch study also showed a significant decrease in learning difficulties for the treatment group. Another study on AMAT-C, undertaken in Sweden, consisted of a randomized controlled study (Treatment group: $n = 18$, Control group: $n = 20$) (10) and a 6-month follow-up study of the same group (20). Results of these studies showed that the children in the AMAT-C treatment group significantly improved their attention and memory functions as compared with the control group. Furthermore, the follow-up study showed that the treatment group maintained significant gains on tests of selective attention and working memory as compared with the control group 6 months after completing the training programme.

In the Swedish studies, it was noted that it could be difficult to maintain the children's motivation throughout the training programme (10,21). Therefore, the following modifications were made: (1) the training period was reduced from 20 to 17 weeks, (2) the level of difficulty was individualized (3) a reward system was used and (4) a schematic outline of the training programme over the 17 weeks was developed.

It is our hypothesis that hospital-based weekly supervision in the Swedish study might be one of the factors that

influenced the children's motivation. This hypothesis became the impetus for this pilot study where seven children with ABI were trained and supervised with AMAT-C in their local school-setting. This is the first study to fully integrate the entire AMAT-C training programme in the school-setting.

This pilot study took place in a rehabilitation setting as part of an outreach programme aiming to keep the child in its usual environment through providing the majority of the services in the child's local area (22). The aim of this study was to determine whether the training programme including the weekly supervision could be integrated in the child's school within the child's normal schedule. There are two reasons for placing supervision at the school: a) to maintain the child's motivation and b) to augment possibilities of transferring trained skills into the child's everyday learning situation (school-setting).

This study thus differs from previous studies mainly in provision of supervision at the child's school. Also, it was decided to complete the full length of the training programme, as far as possible, in the present pilot study.

METHODS

Objectives

The objectives of the study were to investigate (1) whether the training programme can be integrated into the school-setting, i.e. providing training and weekly supervision at the child's school (measured by programme evaluation), (2) whether supervision provided at the school helps maintain the child's motivation throughout the training period (measured by programme evaluation) and (3) whether changes in memory, attention and executive functions are found when supervision is provided in the school-setting (measured by neuropsychological tests and questionnaires).

Participants

Eight children with ABI commenced cognitive training with AMAT-C during the period between 2002 and 2006. Inclusion criteria were attention and/or memory sequelae after ABI (time since injury at least 1 year) and age between 8–16 years. Exclusion criteria were premorbid history of a diagnosed psychiatric disorder or premorbid learning difficulties. One participant did not complete the training programme because of problems related to being trained by two teachers concurrently (one teacher trained the child on certain weekdays, the other teacher on the remaining weekdays). One child was included although the child's time since injury was <1 year (10 months). The reason for inclusion was that allowing him to participate at the given time was the only way that the training could take place before

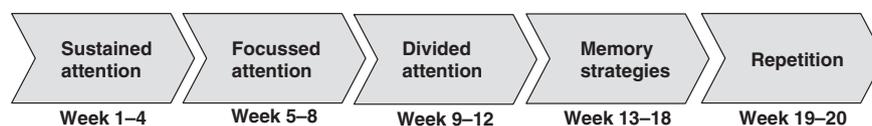


Figure 1 AMAT-C phases and training elements.

Table 1 Characteristics of participants

Child	Gender	Age	Type of injury	Time since injury (years)	Weeks of training	School
A	♂	15.8	Stroke	0.8	20	Ordinary
B	♂	13.8	Traffic accident	1	20	Ordinary
C	♀	13.2	Brain tumour	8	18	Specialist
D	♀	12.8	Traffic accident	8	18	Specialist
E	♂	11.3	Stroke	1	20	Ordinary
F	♀	12.9	Traffic accident	4	18	Specialist
G	♀	14.8	Brain tumour	4	18	Ordinary

he finished school. The group that completed the training programme thus consisted of seven subjects (three male and four female subjects).

Demographic data for each child is shown in Table 1. Mean age at pre-testing was 13.5 ranging from 11–15 years of age (SD = 1.5). Types of brain injury were traumatic (n = 3), brain tumour (n = 2), stroke (n = 2). Time since injury varied between 10 months and 8 years (\bar{x} = 3.8 years, SD = 3.2). Four of the children attended a mainstream school while three attended a special school. The children were recruited through a brain injury rehabilitation facility (22). Unfortunately, information on family social background (such as general family functioning and socio-economic status) was not collected; this is a variable that has previously been shown to influence outcome for children with traumatic brain injury (23).

Materials

The AMAT-C material is published in Dutch, Danish (2005) and Swedish (2008) respectively. The material consists of a trainer's manual, a supervisor's manual, a folder for the child and a number of materials needed for specific exercises. The child's folder includes daily report sheets on which the child notes results for each specific exercise and answers open-ended questions regarding evaluation of performance.

Each week focusses on a specific cognitive skill, the exercises become more challenging throughout the week and each week builds on skills trained OR practised during previous weeks. In addition to the exercises, which are primarily drill-based, AMAT-C includes more metacognitive elements (e.g. 'How do you best remember visual material?'). Weeks 19 and 20 are repetition weeks, during which exercises from the previous 18 weeks are repeated in order to (1) give the child an opportunity to apply all trained skills on previous tasks and (2) to raise the child's awareness of own strategies, strengths and weaknesses.

Programme evaluation consisted of four evaluation questions to parents, trainers and children made specifically to evaluate the AMAT-C training programme. The questions were based on clinical significance, formulated by personnel at the rehabilitation facility and answers were given on a three-point scale (e.g. Very good, Good, Not so good). The questions were as follows: (1) What is your opinion about the training programme? (2) Did you/your child/the pupil want to start doing the programme every day? (3) Is it easier for you/your child/the pupil to concentrate/remember

and/or work with new subjects post-training? (4) Have you noticed other things becoming easier to do post-training? Trainers of the children who completed 20 weeks of training were interviewed about the relevance and significance of the two repetition weeks (weeks 19–20).

Neuropsychological evaluation was carried out using subtests from Wechsler Intelligence Scale for Children III (WISC-III) (24,25), Neuropsychological Assessment of the school-aged child (26,27) and Test of Everyday Attention for Children (TEA-Ch) (28). All children were tested before and after training with AMAT-C. The tests cover the following domains: attention/concentration, tempo, visuo-constructive abilities, learning and memory, and executive functions. See Table S1 (in Supplementary Material online) for specific subtests used.

In order to gain information about the children's behaviour, the Behaviour Rating Inventory of Executive Functions (BRIEF) (29) questionnaire was answered by parents and trainers before and after the training programme.

Data analyses

Answers to one selected evaluation question are described in percentages. The Wilcoxon signed-rank test was carried out to determine differences between pre- and post neuropsychological test results. Statistical tests were made using SPSS (Statistical Package for the Social Sciences; SPSS Inc. Headquarters, Chicago, IL, USA), version 15.0. All given p-values are one-tailed, and $p < 0.05$ is the chosen accepted level of significance.

Certain limitations apply to the use of tests and questionnaires in the chosen battery. There only existed Scandinavian norms for WISC-III. Therefore, American/Australian original norms were applied for the remaining test battery and the BRIEF questionnaire. Furthermore, the study target group differed from the normative population in some of the test batteries. With respect to age, the chosen procedure was that raw scores of children who were younger/older than the norm groups were converted using norms of the youngest/oldest groups respectively. Some raw scores were converted to stanine (abbreviation for 'standard nine') scores based on the norms available. The mean of the stanine measure is 5 and the standard deviation is 2.

Procedures

One of the children's regular teachers was chosen as trainer and carried out the daily training with the child. Weekly supervision was provided by personnel from the

rehabilitation facility. Supervision was provided at the school with participation of supervisor, trainer and child and lasted 30–45 min. The supervisor takes over the training session and acts as trainer for the child while the trainer observes. The purpose of the weekly supervision is to not only explain and demonstrate the following week's training elements but also to evaluate the past week's training.

The supervisor had access to the child's neuropsychological testing, which facilitated adapting and individualizing the cognitive training to the child's specific strengths and weaknesses. If the full 20 weeks of training was completed, the child had trained for 100 sessions on a one-to-one basis. Given smaller breaks for holidays, illness, project weeks, school camps etc., a full training period typically varied in duration from 6 to 9 months.

The children were tested by trained child neuropsychologists within 3 weeks prior to commencement and within 3 weeks after completion of the training programme.

All seven children were trained by one of their teachers at school within normal school hours. Four children trained for 18 weeks while three trained for 20 weeks. The length of the training depended on practical issues such as resources at the child's school and unexpected illness. Therefore, some programmes ended at 18 weeks in order to complete the training before the school holidays.

RESULTS

Programme evaluation

All parents, trainers and children answered evaluation questions. Overall, responses were positive, as can be expected when such an extensive intervention has been carried out. We have therefore chosen only to focus on one question here, as it pertains to the children's motivation, namely: *Did you/your child/the pupil want to start doing the programme every day?* The parent(s) of one child did not answer this question. Responses are given in percentages and distribution of responses as well as number of replies is shown in Table 2.

All trainers and parents reported that the children 'often' wanted to start the training session. This does not quite correspond to the children's replies as six children (86%) answered that they 'sometimes' wanted to start the training and one child (14%) answered 'often'.

Besides answering on a three-point scale, respondents were given space to comment on question number four (whether they noticed any things besides memory and attention becoming easier post-training). Examples of the comments are given in Table 3.

The comments indicate that skills and behaviour not directly related to the children's cognitive impairment improved after the training programme.

Neuropsychological evaluation

The neuropsychological test results showed that the children as a group achieved better results in terms of higher-scaled scores and improved speed after having completed the training programme than they did prior to the training.

Table 2 Distribution of responses to the question of whether the child wanted to start the training

	Often (%)	Sometimes (%)	Not at all (%)
Child (n = 7)	14	86	0
Parent (n = 6)	100	0	0
Trainer (n = 7)	100	0	0

Table 3 Comments to the evaluation question 'Have you noticed other things becoming easier to do post-training?'

Respondent	Comment
Child	'Math and written assignments seem easier for me to do as well as learning techniques at basketball practice and remembering TV programmes'.
Child	'Remembering things if I have made plans'.
Parent	'Personally, I have gained a better contact with her'.
Parent	'He has become more aware of his own situation'.
Parent	'She manages her temper better'.
Trainer	'It is easier to get her started - by referring to tasks from the training programme'.

Also, statistically significant improvements were seen on tests of attention (one of 11 subtests), tempo (one of four subtests), visuo-constructive abilities (one of one subtest), learning and memory (four of seven subtests) and executive functions (one of five subtests). An overview of the neuropsychological results is presented in Table S1 (in Supplementary Material online).

Questionnaire results on executive functions

The questionnaire results (BRIEF) from the parental responses for the children as a group showed an increase in T-scores indicating that the parents observed a slight negative change in the children's executive functions post-training. The trainers, on the other hand, reported a decrease in T-scores indicating a positive change in the children's executive functions. There was one positively significant result in the trainer responses indicating that the children as a group improved their emotional control significantly post-training. An overview of the questionnaire responses is given in Table S2 (in Supplementary Material online).

DISCUSSION

Answers to the evaluation questions indicate that motivation for beginning each training session was maintained throughout the programme, although parents and trainers rate this more positively than the children. However, as the children were satisfied with the programme overall, we believe that they were able to keep up motivation throughout the programme, whether it lasted 18 or 20 weeks. This is very positive in light of previous reported difficulties with maintaining motivation (10,21). One explanation for the children's maintained motivation could be that the supervision did not take place at the hospital, a place that could be associated with their illness/injury. Also,

everyday school life is less disturbed when supervision takes place in the child's school, giving possibility of more classroom participation, with respect to both curriculum and social activities.

Comments from trainers, parents and children regarding issues other than memory and attention becoming easier post-training indicate that AMAT-C training affects other aspects of the child's everyday life. While this may be related to improved memory and attention (3) it could also be attributed to the close co-operation between trainer and child.

Feedback from the trainers of the three children who completed the full 20-week programme suggested that the two repetition weeks added greatly to the programme. The trainers stressed that the children who went through the repetition phase benefited from experiencing how much better they had become at tasks that initially required a much greater effort, which confirmed the supervisors' clinical observations of the positive effect of the repetition weeks.

As mentioned, four children attended ordinary school while three attended a special school. Based on the positive programme evaluation from all participants, it appears that AMAT-C is useful in both settings.

As there is no control group included in this study, it is not possible to determine to what extent improvements on the neuropsychological tests can be considered valid or simply be attributed to practice effect (time from pre- to post-testing was on average 8 months) (30). However, the statistical data analysis was made on standard scores rather than raw scores. Significant improvements on normed neuropsychological tests are noteworthy, as children with memory and/or attentional problems after ABI generally have a decelerated learning curve as compared with non-injured peers (31).

In light of the positive results in the controlled Swedish study (10,20), and given the fact that the data analyses in this study were carried out on scaled scores, we would suggest that the statistically significant results presented in this article signify a positive effect of the AMAT-C training on the children's memory and attention skills, although these results should be interpreted with caution. For instance, the improved speed found in this study should not be attributed to the AMAT-C training alone as there was no significant difference in tests of reaction time between the treatment and the control group in the Swedish study (both groups improved their reaction time).

This is the first AMAT-C study where executive functions are evaluated through questionnaires. Unfortunately, results from the BRIEF questionnaire responses do not show an overall improvement in function. In fact, the parents report a significant worsening within two domains. This 'worsening' of the parents' responses can be seen after rehabilitation and may be explained by the increase in knowledge about the child's difficulties that parents gain as part of the rehabilitation efforts. Also, it should be noted that results of the parental responses before as well as after the training programme are within the normal range.

It is our clinical experience that the programme opens up several possibilities for generalizing skills acquired through the training to everyday situations. These possibilities for transfer arise because (1) the material incorporates metacognitive elements in the daily training sessions, (2) the training involves use of everyday situations such as applying learned AMAT-C methods to reading assignments and because (3) the daily one-to-one sessions in the school-setting often improves the pupil-teacher relationship.

Time post injury varies a great deal for the children in the study and is a factor which could influence motivation and improvement. However, it has not been possible to investigate the importance of time since injury statistically because of the small number of subjects. Our clinical experience from this study as well as later AMAT-C training supervised from our rehabilitation facility does not indicate a particular pattern between time since injury and motivation and/or cognitive or other improvements after AMAT-C.

Finally, we wish to stress that pilot studies such as this are necessary in order to refine and improve rehabilitation interventions. Without such pilot studies it is not possible to evaluate adapted implementations of an intervention programme, an essential step if considering a larger study and possible inclusion into clinical care.

LIMITATIONS

There are several limitations to this study. As is often seen in pilot studies, there were only a small number of subjects, and no control group was included. Furthermore, although one purpose of placing intervention in the school-setting was to augment possibilities of transferring trained skills to the child's everyday learning context, there was no measure for such transfer. In other words, there could have been a greater focus on functional outcome measures.

Unfortunately, this study did not examine what the effective component of the AMAT-C programme is (this is also the case for the other AMAT-C studies undertaken to date). Our clinical experience is that positive effects are attributable to the multifactorial efforts including the child's gained insight into his/her own cognitive strengths and deficits, the cognitive training per se as well as the explicit metacognitive elements of the training programme.

FUTURE DIRECTIONS

Based on the fact that one child that did not complete the training programme because of having two concurrent trainers, we recommend that there be only one trainer and that it is the same trainer throughout the training programme. Having more than one trainer places too much responsibility on the child with respect to keeping track of process and progression.

Also, based on the positive feedback concerning the two repetition weeks, we recommend that in planning future training setups that the 20-week of training be chosen.

Although we see considerable advantages in providing supervision in the child's school, we recognize that this is a

very costly solution. Therefore, a less costly way of providing supervision in the local setting could be considered e.g. supervision to the trainer by phone or supervision to child and trainer by webcam.

CONCLUSION

First, this pilot study shows that the AMAT-C programme can successfully be integrated into the child's school within the child's normal school schedule. Second, the study suggests that school-based supervision may have a positive influence on the children's motivation. Third, improvements on neuropsychological tests are also seen when training and supervision takes place in the school-setting. In summary, school-based implementation of the supervision seems promising and further research is needed to confirm the results and conclusions presented in this article.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1 Neuropsychological test results.

Table S2 Results from the behaviour rating inventory of executive function.

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