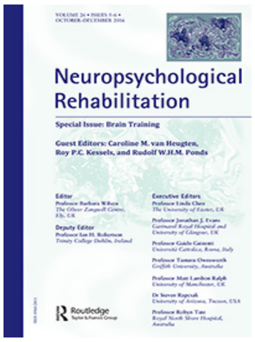


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# ORIGINAL ARTICLE

# Cognitive training approaches to remediate attention and executive dysfunction after traumatic brain injury: A single-case series

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Attentional deficits are common following traumatic brain injury (TBI) and interfere with daily functioning. This study employed a single-case design to examine the effects of individualised strategy training on attention beyond the effects of computerised training using Attention Process Training 3 (APT-3), and to examine the participants' subjective experience of these approaches. An ABCA (baseline, APT-3, strategy training, follow-up) design was repeated across three participants with severe TBI. Outcomes were measured on alternate

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versions of the oral Symbol Digit Modalities Test (SDMT) and cancellation tasks; generalisation with the Test of Everyday Attention (TEA) and self and significant other (SO) ratings on the Rating Scale of Attentional Behaviour (RSAB); and participant experiences with semi-structured interviews. Planned Tau-U analyses revealed improvements in speed of processing on the SDMT and the automatic condition of the cancellation task after APT-3 and at follow-up, but with most improvement after strategy training. Limited generalisation was evident on TEA subtests and self-RSAB ratings. SO-RSAB ratings were mixed after APT-3, but demonstrated improvement after strategy training. Variability in attentional deficits and everyday attentional requirements between patients required individualised goals and approaches to rehabilitation. This study highlights the need for individualised rehabilitation of attention to improve everyday functioning after TBI.

***Keywords:*** Computer training; Strategy training; Traumatic brain injury; Attention; Rehabilitation.

## INTRODUCTION

Deficits in attention are common and debilitating following traumatic brain injury (TBI; Olver, Ponsford, & Curran, 1996). The most prevalent attentional difficulties after TBI include deficits in speed of processing, attentional capacity, sustained and selective attention, and supervisory attentional control (Mathias & Wheaton, 2007). Attentional difficulties can interfere with many aspects of daily functioning (Lewis & Horn, 2013) so remediation is important. Problems with memory (Mangels, Craik, Levine, Schwartz, & Stuss, 2002), executive functioning (Spikman, Deelman, & van Zomeren, 2000), mood and sleep–wake disorders (Ponsford et al., 2014) may overlap with attentional difficulties and need to be addressed in the remedial process.

The most common method of attentional rehabilitation has been training on computer-based programmes (Ponsford & Willmott, 2004). Computer training is based on the restorative approach, which assumes that repetitive training on attentional tasks restores underlying damaged neural networks (Park & Ingles, 2001).

One such programme, Attention Process Training 3 (APT-3; Sohlberg & Mateer, 2010), is a hierarchical, multilevel direct attention training computer programme designed to remediate attention after brain injury. Sohlberg et al. (Sohlberg & Mateer, 1987; Sohlberg, McLaughlin, Pavese, Heidrich, & Posner, 2000) demonstrated improvements on the Paced Auditory Serial Addition Task (PASAT) after APT training. However, in a meta-analysis of 30 studies of attention retraining after TBI, Park and Ingles (2001) found that pre–post studies demonstrated large effect sizes which tended to be significant, whereas pre–post with control estimates tended to show small and non-significant effects. The authors attributed the training gains to practice effects or acquisition of specific skills (i.e., responding quickly and accurately on time pressure tasks). Guidelines for attention training following TBI do not recommend reliance on repetition of computerised attention tasks due to limited evidence of generalisation to everyday attentional abilities (Bayley et al., 2007; Ponsford et al., 2014). However, Cicerone et al. (2011) and Sohlberg et al. (2003) suggest attention training may be helpful in conjunction with clinician-guided metacognitive training.

Metacognitive strategy training, environmental modification and use of assistive technology represent alternative or complementary treatments to computer-based attention training. These approaches are based on the functional compensation approach which aims to augment an individual's strengths through skill and strategy acquisition to compensate for cognitive impairments (Sloan & Ponsford, 2013). The therapist works with the individual with TBI to select goals, and teach and practise meaningful and relevant skills required to enhance performance on everyday tasks. Metacognitive strategy training may focus on internal (e.g., self-talk, mindfulness, etc.) and/or external (e.g., note taking, asking for repetition, etc.) compensatory strategies.

Compensatory approaches trialled successfully in people with TBI include Time Pressure Management (TPM), Goal Management Training (GMT), and auditory cueing. The focus of TPM is reducing the impact of slowed speed of thinking, whereby individuals are taught to recognise, prevent and manage time pressure and to monitor strategy use (Fasotti, Kovacs, Eling, & Brouwer, 2000). GMT promotes goal attainment by teaching the stages of goal planning, implementation and error monitoring (Robertson, 1996; cited in Levine et al., 2000). The additional provision of auditory alerting tones (Manly, Hawkins, Evans, Woldt, & Robertson, 2002) or "STOP!" text messages (Fish et al., 2007) maintains focus on selected tasks. Guidelines recommend metacognitive strategy training to remediate attentional deficits, particularly for individuals with mild to moderate attentional impairments and adequate self-awareness (Cicerone et al., 2011; Ponsford et al., 2014; Sohlberg et al., 2003). In contrast, individuals with severe attentional impairments after TBI may benefit from environmental and task modification, including minimising distractions and changing task demands to reduce cognitive load and the need for speed, switching or sustaining of attention (Ponsford et al., 2014; Sloan & Ponsford, 2013).

To date, there has been limited documentation of the experience of individuals undertaking either computer-mediated or real-world strategy training. The aim of the current study was to use a single-case experimental design to examine the effects of individualised strategy training beyond the effects of APT-3 on performance on tests of attention, generalisation to an ecological attentional task and rating scales of everyday attentional behaviour, and to examine subjective experience of these approaches. It was hypothesised that individualised strategy development would enhance performance on neuropsychological tests of attention and result in generalisation on an ecological attention task and subjective ratings of everyday attentional behaviour beyond the effects of APT-3.

## METHOD

The study was approved by the Epworth HealthCare and Monash University Human Research Ethics Committees and all participants gave informed, written consent.

### Participants

Three participants with a history of severe TBI (duration of post-traumatic amnesia $>$ 7 days; Department of Veteran Affairs & Department of Defense, 2009) were recruited from Epworth HealthCare, Melbourne, Australia. Participants varied in age (21–53 years), years of education (12.5–16 years) and time since injury (1–7 years). All participants spoke English as their first language, had sufficient cognitive function to engage in therapy and assessment tasks, and had no history of previous psychiatric or neurological illness. Participants also had self- or family-report of reduced processing speed or attentional difficulties and demonstrated impaired performance ($>$ 2 standard deviations below normative data) on the oral Symbol Digit Modalities Test (SDMT; Smith, 1991) at baseline. CC experienced right (dominant) sided motor weakness and diplopia. Demographic information is presented in Table 1.

In terms of everyday functioning, AA had recently completed a degree and was seeking employment, BB was employed full-time and CC was participating in part-time work and rehabilitation (physiotherapy, occupational therapy and psychology) during the study. All participants were living with family in the community.

AA and CC were familiar with brain training, both having previously used Lumosity™ post-TBI. Both reported using the programme for short periods (usually minutes) intermittently, with AA using it for a "few years" whereas CC had used it for a "few months". BB had not used computer brain training prior to study participation.

### Design

The study used a single-case ABCA (i.e., baseline, APT-3, strategy training, follow-up) experimental design repeated across participants. It was not

TABLE 1
Demographic and injury characteristics of the participants

| *Participant* | *Age (years)* | *Education (years)* | *Cause of injury* | *PTA duration (days)*[a] | *Worst GCS Score* | *Time since injury (years)* | *Location of lesion* |
|---|---|---|---|---|---|---|---|
| AA | 27 | 16 | Car accident | 88 | 7 | 7 | Intracerebral bleed over tentorium; small petechial frontal contusions |
| BB | 53 | 15 | Cycling accident | 11 | 13 | 2 | DAI; right frontal and temporal lobe haemorrhages; diffusion restriction in right thalamus and left caudate |
| CC | 21 | 12.5 | Car accident | 83 | 5 | 1 | DAI; right frontal parafalcine and tentorial subdural haemorrhage |

[a]Measured using the Westmead PTA Scale (Shores, 1995).
PTA = Post-traumatic amnesia; GCS = Glasgow Coma Scale; DAI = Diffuse axonal injury.

feasible to randomise the order of interventions as strategies learned during strategy training may have been transferred to APT-3 tasks. Baseline and follow-up phases comprised nine assessment sessions whilst APT-3 and strategy training phases comprised 18 sessions each (nine assessments and nine intervention sessions). Each phase lasted 3–4 weeks and the study ran for 12–16 weeks in total. Participants were asked to refrain from completing any other computerised attention training throughout the study. Single-case methodology quality indicators were followed as far as possible in the design, analysis and reporting of this trial (Tate et al., 2008, 2013).

## Materials

### *Outcome measures*

The oral SDMT (Smith, 1991) was used to measure information processing speed whilst avoiding effects of motor weakness. Participants inspected a sequence of symbols then searched a key to substitute the corresponding number for each symbol. Four alternative forms were used (Hinton-Bayre & Geffen, 2005). The number of items correctly and incorrectly completed in 90 seconds was recorded.

Pencil and paper cancellation tasks were used to measure speed and selective attention. One condition consisted of the Ruff 2 and 7 Selective Attention Test (Ruff & Allen, 1995) where participants cancelled the numbers 2 and 7. The investigators created similar cancellation tasks requiring participants to cancel 3 and 6, or 4 and 9 to minimise practice effects. Digits were embedded amongst letters (automatic condition) or other numbers (controlled condition). Each administration comprised 10 automatic and 10 controlled trials of 15 seconds duration. Number of digits correctly identified and accuracy were recorded for each condition (Automatic Speed Raw Score: ASRS; Controlled Speed Raw Score: CSRS).

### *Measures of generalisation*

The Test of Everyday Attention (TEA; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994) was used to measure generalisation of gains. The TEA uses ecologically valid tasks to assess several attentional domains. Sustained attention was assessed by Elevator Counting, Telephone Search while Counting (dual task decrement), and Lottery subtests. Visual selective attention/speed was measured with Map Search (1 and 2 minutes) and Telephone Search subtests (time per target). Attentional switching was assessed via the Visual Elevator task (accuracy and timing). Auditory-verbal working memory was assessed with Elevator Counting with Distraction and Elevator Counting with Reversal subtests. Version A, B and C were completed, respectively, at baseline, APT-3 and strategy training.

The Rating Scale of Attentional Behaviour (RSAB; Ponsford & Kinsella, 1991) was developed and validated for therapists to monitor functional attention of individuals with TBI. The 14-item scale measures alertness, processing speed, sustained attention, distractibility, dual-tasking and attention to detail. Frequency of attentional difficulties was rated on a 5-point Likert scale from "Not at all" to "Always", with total score ranging from 0 to 56 (higher scores represent greater attentional difficulties in everyday life). A modified version was created to allow self-report of everyday attentional difficulties. The RSAB was completed by the participant and their significant other (SO) after each phase.

### *Semi-structured interviews: Participant perceptions of the interventions*

Semi-structured interviews and rating scales were completed after the APT-3 and strategy training phases to explore participants' experience of these interventions. Questions probed: (1) number of strategies learned; (2) frequency of implementing strategies in everyday life; (3) usefulness in minimising the impact of attentional difficulties; (4) change in confidence in managing attentional difficulties; (5) change in daily activities; (6) satisfaction with balance of activities in everyday life; (7) willingness to continue with a therapist; (8) willingness to complete activities on their own; (9) enjoyment of the intervention; and (10) overall satisfaction with the intervention. Participants responded on a five point Likert-type scale, with higher ratings corresponding to more positive responses. Open ended questions probed the most and least helpful aspects of interventions, strategies which were implemented most frequently, and changes in everyday functioning.

### *Intervention materials*

*Attention Process Training 3*. APT-3 (Sohlberg & Mateer, 2010) is a computerised direct attention training programme designed to improve attention deficits following acquired brain injury through repetition of auditory and visual tasks. The APT-3 programme classifies tasks according to five domains of attention: sustained attention, selective attention, working memory, suppression, and alternating attention. The researchers ranked the APT-3 tasks within each domain into a hierarchy according to complexity, rate of presentation, and level of distraction. Order of task presentation was adaptive with task difficulty matched to each individual's current level of attentional functioning. Number of levels included were 34 for sustained attention, 184 for selective attention, 35 for working memory, 40 for suppression and 38 for alternating attention. APT-3 was individually administered to each participant by the therapist. Participants moved through the tasks according to the following researcher created guidelines: skip level(s) if accuracy $> 90\%$; progress a level if accuracy $\geq 80-90\%$; repeat level if accuracy is 70–79%; regress level(s) if accuracy is $< 70\%$ or the participant refuses to complete a task because it is too frustrating. As the aim was to distinguish the effects of strategy training beyond the effects of computer training, metacognitive strategy training was not used in conjunction with APT-3. Thus, participants were able to review their performance after each task but were not provided with coaching, feedback or strategies during APT-3.

*Individualised strategy training.* The strategy training was conducted one-on-one and individualised according to each participant's everyday attentional difficulties. At baseline participants were provided with an attention log in which they recorded instances of attentional difficulties experienced in everyday life. Whilst the content was reviewed during baseline and APT-3 phases to encourage completion, feedback and strategies were not provided until commencement of the strategy training phase. Session one consisted of psychoeducation about domains of attention, and targets for strategy training were selected based on difficulties raised during this session and in the participant's attention log. Goal Attainment Scaling (GAS; Kiresuk & Sherman, 1968) was completed to guide future strategy training sessions and assess the accomplishment of goals. Five levels are delineated, ranging from +2 to −2, reflecting outcomes that are: (+2) "much more than expected"; (+1) "more than expected"; (0) "expected outcome"; (−1) "less than expected"; and (−2) "much less than expected". Baseline was rated as −1 except when worse performance was not considered possible, in which case baseline was rated as −2 (Turner-Stokes, 2009). GAS was rated by the individual with TBI in cooperation with the therapist during the first individualised strategy training session, upon completion of this phase and at 3-week follow-up.

The specifics of strategy training differed between individuals according to goals. All participants completed at least one session on attentional strategies (e.g., minimising distractions, goal setting, environmental cueing, using incentives, working at your best time, doing one thing at a time, applying structure and self-monitoring). Strategies for time management difficulties included prioritisation, GMT, STOP! text message prompts and brief alerting tones. TPM was taught when reduced speed of information processing interfered with daily functioning. Internal memory strategies (chunking, repetition, associations, acronyms), external memory strategies (routine, adapting environment, mobile phones, notes, white boards, watches, lists, timers) and strategies to remember names were taught to participants reporting memory difficulties. Cognitive-behavioural therapy (CBT) and mindfulness (including deep breathing, visualisation and progressive muscle relaxation) were provided to participants whose anxiety interfered with their attentional functioning. Finally, fatigue and sleep hygiene education was important in encouraging participants to take breaks and maximise rest periods. Homework was provided at the end of each session and included applying newly learned strategies to everyday tasks, with review and discussion of barriers to implementation at the following session. Goals were regularly reviewed and material was revisited as required.

## Procedure

Following informed consent, all participants completed four phases: (1) baseline; (2) APT-3; (3) individualised strategy training; (4) follow-up. The SDMT and cancellation tasks were administered nine times per phase by independent researchers blinded to treatment phase and protocol. The APT-3 and strategy training sessions were conducted by a doctoral clinical neuropsychology student (A. Dymowski) under the supervision of experienced clinical neuropsychologists (C. Willmott and J. Ponsford). The follow-up phase involved a return to baseline conditions to examine maintenance of gains after completion of the intervention. Sessions were conducted at the clients' homes, Monash University or Epworth Hospital.

### *APT-3 intervention*

During the APT-3 phase participants completed nine 1-hour treatment sessions. Participants completed eight APT-3 tasks during each session consisting of at least one from each category per day. Each participant completed 72 computer tasks consisting of 15 sustained and 15 selective attention, 14 working memory, 14 suppression and 14 alternating attention tasks.

### *Individualised strategy training intervention*

The individualised strategy training was delivered in nine 1-hour sessions, with the first session devoted to identifying and setting goals and other sessions providing training in individualised strategies. Each individual's subgoals, baseline GAS level, expected GAS outcome and assistive strategies are shown in Table 2. A motivating goal for AA was to gain employment, however several cognitive difficulties interfered with his job-seeking and everyday activities. Subgoals included improving time management skills (i.e., ranking priorities and planning) and increasing time spent on productive tasks. BB's goals focused on ameliorating his difficulty managing his work–life balance (i.e., completing hobbies during work hours) and anxiety interfering with his productivity at work. CC experienced slowed thinking so his goals were to improve his attentional skills in order to remember more information and to pay attention when being introduced to people to assist recall of

TABLE 2
Participant subgoals and assistive strategies

| Participant | Patient-generated/patient-focused goals | Baseline performance (GAS level) | Expected outcome (GAS = 0) | Assistive strategies |
|---|---|---|---|---|
| AA | (1) To rank priorities | Does not rank priorities: Does easy, less urgent and pleasurable tasks first (−2) | To rank priorities with guidance over 50% of the time | • To do list<br>• Ranking priorities (1st Vital; 2nd Important; 3rd Nice)<br>• Use diary/phone to schedule events<br>• STOP! Text messages<br>• Alerting tones<br>• TPM<br>• GMT<br>• Environmental modification<br>• Attention and memory strategies<br>• Fatigue and sleep hygiene |
| | (2) To make plans and follow them | Does not make plans: Fails to use planner, fails to complete tasks (−2) | To make written plans and follow them to completion 50% of the time | |
| | (3) To be able to stay on task | Able to stay on task for a few minutes (−2) | Able to complete a task for 30 minutes before getting distracted | |

(*Continued*)

TABLE 2 Continued.

| *Participant* | *Patient-generated/patient-focused goals* | *Baseline performance (GAS level)* | *Expected outcome (GAS = 0)* | *Assistive strategies* |
|---|---|---|---|---|
| BB | (1) To feel like completed a full day (7 hours) at work without getting distracted or side-tracked | To feel like completed 3 to 4 hours at work (−1) | To feel like completed 5 hours at work | • Modified Covey (2004) time management matrix<br>• Use of whiteboards and phones to plan and organise<br>• STOP! Text messages |
| | (2) To manage anxiety about being late, which interferes with concentration at work | Difficulty concentrating and easily distracted at work due to anxiety about being late to appointments, with use of some strategies (−1) | Uses cognitive and behavioural techniques to minimise the impact of anxiety on attention, although some anxiety and lapses in attention still occur | • Alerting tones<br>• Boundary setting<br>• CBT for anxiety: deep breathing, visualisation<br>• Mindfulness for anxiety: focusing on a focal point, progressive muscle relaxation<br>• Attention strategies<br>• Fatigue and sleep hygiene |
| CC | (1) To improve attentional skills in order to remember more information | Uses few strategies to remember information and often forgets important information (−1) | Uses compensatory strategies to remember information, occasionally forgetting important information | • Attention strategies<br>• TPM<br>• Strategies to remember names |
| | (2) To pay attention when being introduced to people | Does not use strategies to remember names and frequently forgets names (−2) | Uses attentional techniques to remember new names, and occasionally forgets names | • Internal memory strategies<br>• External memory strategies<br>• Fatigue and sleep hygiene |

GAS = Goal Attainment Scaling; TPM = Time Pressure Management; GMT = Goal Management Training; CBT = Cognitive-behavioural therapy.

names. Assistive strategies were developed around each participant's goals as shown in Table 2.

### *Assessment of generalisation and impressions of interventions*

To assess generalisation of gains, the TEA was conducted by blinded researchers on completion of baseline, APT-3 and strategy training phases. The RSAB was completed by participants and a significant other after each of the phases. The semi-structured interview was completed after the APT-3 and strategy training phases. On completion, participants were asked, hypothetically, to choose between continuing with computer training or strategy training and to justify their response.

## Data analysis

### *Inter-rater reliability*

Inter-rater reliability (IRR) was calculated including 20% of the data for each phase and each participant on the SDMT and cancellation tasks. Overall percentage agreement was 99.9% for the SDMT, 98.6% for ASRS and 98.9% for CSRS.

### *Dependent variables*

Initial analyses aimed to assess whether individuals improved on each intervention. Progression through the APT-3 levels was displayed graphically and quantified using linear regression in GraphPad Prism 6 to assess whether the slope in each domain differed significantly from 0.00. For strategy training, GAS level was recorded prior to strategy training, post-strategy training and at 3-week follow-up.

Outcome performance data were analysed both visually and statistically. Visual analysis was conducted according to the method recommended by Lane and Gast (2014), including within and between condition analyses (only between condition analyses presented).

Planned comparisons were conducted to investigate intervention effects. Following Gast and Spriggs' (2009) assertion, only adjacent conditions were directly compared. Baseline was compared with APT-3 to investigate the effect of computer training on attention. APT-3 and individualised strategy training were compared to examine gains from the latter training beyond the former training. Finally, individualised strategy training and follow-up were compared to explore maintenance of gains.

Planned comparison Tau-U analyses were conducted for each participant to investigate whether there were significant improvements in attention between phases. Tau-U is a nonparametric technique measuring data non-overlap between two conditions with the option of controlling for positive baseline trend (Parker, Vannest, Davis, & Sauber, 2011). This method is appropriate for single-case research where data may not adhere to parametric assumptions (Brossart, Vannest, Davis, & Patience, 2014). Tau-U calculations were performed via the website: http://www.singlecaseresearch.org/calculators/tau-u (Vannest, Parker, & Gonen, 2011). Where necessary, initial trend (i.e., baseline, APT-3 or strategy training) was controlled in comparisons.

To assess generalisation, TEA raw scores were calculated. To be consistent across comparisons, change in performance from baseline to APT-3 (version A to B) and from APT-3 to strategy training (version B to C) were interpreted on the basis of practice effects from version B to C as outlined in the TEA manual, with improvement or worsening found in less than 7% of the population noted. There are no significant practice effects on the Lottery task (Robertson et al., 1994) so any change in raw scores was noted as significant. RSAB results were analysed visually.

# RESULTS

## Training progression

### *Computerised training: APT-3*

The progression of each participant through the hierarchical levels of the APT-3 domains is shown in Figure 1. Statistical analyses revealed that slopes of trend lines were significantly different from 0.00 across all participants and all domains of attention (all *p*s $< .0001$), suggesting that all participants progressed to more challenging levels in each domain.

### *Individualised strategy training*

Participant goals achieved after strategy training were generally maintained at follow-up (see Table 3). AA remained at baseline levels for ranking priorities but demonstrated improved time management skills and on-task behaviour in preparation for work readiness. BB demonstrated improvements in work–life balance and ability to manage anxiety interfering with attention, and CC's attentional skills improved in order for him to remember information and names.

## Outcome measures—SDMT and cancellation tasks

Accuracy data for the SDMT and cancellation tasks were stable around the median, with participants performing at or close to ceiling. Hence, only

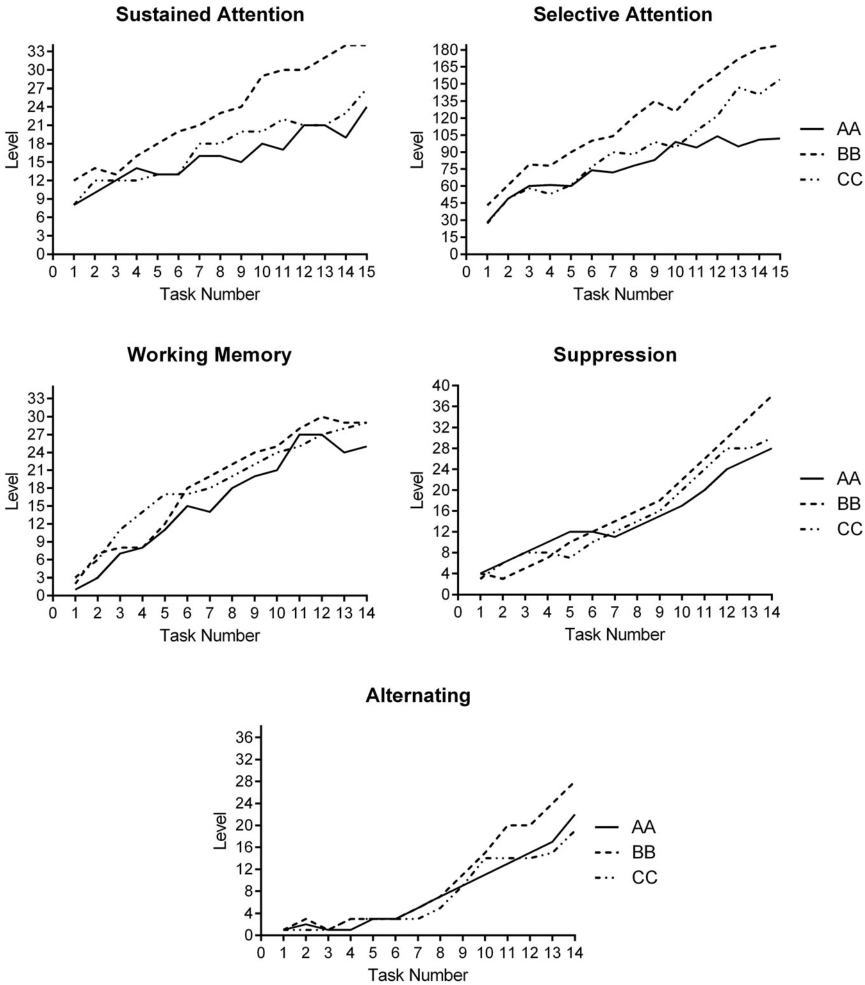


**Figure 1.** Participant progression through the hierarchy of APT-3 tasks within each attention domain.

number of items correctly completed are presented. AA missed a session in baseline and follow-up phases (8 points in these phases) whilst BB and CC completed all assessments (9 points per phase). One SDMT administration to CC during the APT-3 phase was excluded as an extremely low outlier. Only one variable (type of training) was introduced for each participant during the APT-3 and strategy training. However, AA completed neuropsychological assessment and received feedback for clinical purposes during the follow-up phase.

TABLE 3
GAS scores for participants at baseline, post-strategy training and follow-up

| *Participant* | *Goal* | *Pre-strategy training* | *Post-strategy training* | *Follow-up* |
|---|---|---|---|---|
| AA | Rank priorities | −2 | −2 | −2 |
| | Plan | −2 | −1 | −1 |
| | Stay on task | −2 | 0 | 0 |
| BB | Complete full day of work | −1 | 1 | 2 |
| | Manage anxiety | −1 | 1 | 1 |
| CC | Improve attentional skills | −1 | 1 | 1 |
| | Pay attention during introductions | −2 | 0 | 0 |

GAS = Goal Attainment Scaling. Levels range from +2 to −2: +2 = much more than expected; +1 = more than expected; 0 = expected outcome; −1 = less than expected; and −2 = much less than expected (Kiresuk & Sherman, 1968).

### *SDMT results*

Figure 2 shows the SDMT performance of participants across conditions. Visual analyses indicated an improvement from baseline to APT-3 for BB, however no participants showed statistically significant improvement across these phases. Visual analyses demonstrated improvement from APT-3 to strategy training for all participants, which was statistically significant for AA and CC. There was visual improvement for AA and CC from strategy training to follow-up, which was significant only for AA (see Table 4).

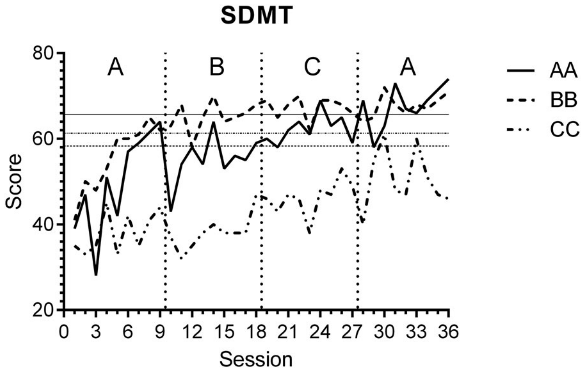


**Figure 2.** Participant performance on the SDMT task throughout the research. A = baseline; B = APT-3; C = strategy training; A = follow-up. The control mean for each participant's age and education (Smith, 1991) is shown according to the key.

TABLE 4
Tau-U results of planned comparisons for participants on SDMT and ASRS and CSRS cancellation tasks

| | *Baseline vs. APT-3* | *APT-3 vs. strategy training* | *Strategy training vs. follow-up* |
|---|---|---|---|
| SDMT | | | |
| AA | .06# | .79** | .58* |
| BB | .42# | .41 | .00 |
| CC | .04 | .56#* | .37 |
| Cancellation task ASRS | | | |
| AA | .07 | .85** | .47 |
| BB | .62#* | .37# | .32 |
| CC | .80** | .53 | .62* |
| Cancellation task CSRS | | | |
| AA | .36 | .26 | .24 |
| BB | .53# | .44 | .10 |
| CC | .27# | .37 | .07 |

#Comparison controlled for trend in initial phase.
*Significant at $p \leq .05$; **Significant at $p \leq .01$.
SDMT: Symbol Digit Modalities Test; ASRS: Automatic Speed Raw Score; CSRS: Controlled Speed Raw Score.

### *Cancellation task automatic results*

For ASRS data, see Figure 3(a), performance of AA and CC remained below normative expectations throughout the study, whereas BB achieved average levels during the baseline phase. For between condition analyses, BB and CC demonstrated significant improvements from baseline to APT-3, consistent with visual analyses. Whilst all participants demonstrated improvement on visual analyses from APT-3 to strategy training, and strategy training to follow-up these findings were only significant for AA for the former comparison and CC for the latter comparison (see Table 4).

### *Cancellation task controlled results*

AA and CC's cancellation task controlled performance remained below normative data throughout the study whereas BB's performance surpassed average levels within the baseline phase, see Figure 3(b). Visual analyses demonstrated improvements from baseline to APT-3 for all participants, from APT-3 to strategy training for AA and BB, and from strategy training to follow-up for BB and CC, however none of these findings was statistically significant (Table 4).

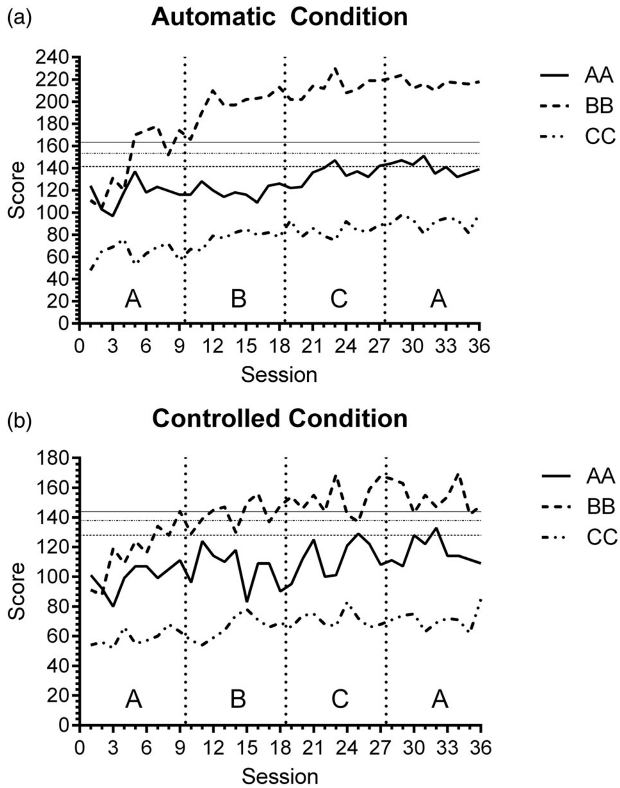


**Figure 3.** Participant performance on the cancellation task automatic (a) and controlled (b) conditions. A = baseline; B = APT-3; C = strategy training; A = follow-up. The control mean for each participant's age and education is shown according to the key.

## Generalisation results

### *TEA results*

All participants reached ceiling (7/7: Normal) on the Elevator Counting subtests at each presentation, therefore these task results were not further investigated. Raw scores on TEA subtests are presented in Table 5. Limited generalisation was observed on TEA subtests, with all patients demonstrating equivocal results. Specifically, across participants there was significant improvement on three subtests and deterioration on four subtests after APT-3, and significant improvement on three subtests and deterioration on three subtests after individualised strategy training. Significant decreases in attentional performance may reflect lapses in attention, reduced motivation

TABLE 5
TEA sub-test raw score results for all participants

| | *Visual Selective Attention/Speed* | | | *Sustained Attention* | | *Attention Switching* | | *Auditory-Verbal Working Memory* | |
|---|---|---|---|---|---|---|---|---|---|
| *Participant Phase* | *MS1* | *MS2* | *TS* | *TSC* | *L* | *VE1* | *VE2* | *ECD* | *ECR* |
| AA | | | | | | | | | |
| Baseline | 35 | 67 | 2.7 | 0.7 | 8 | 9 | 5.4 | 9 | 4 |
| Post APT-3 | 36 | 71 | 3.6− | 0.7 | 10+ | 10 | 5.3 | 9 | 5 |
| Post-strategy | 37 | 70 | 4.6− | −1.4 | 8− | 8 | 4.3+ | 10 | 7 |
| BB | | | | | | | | | |
| Baseline | 35 | 55 | 3.0 | 0.4 | 10 | 10 | 3.6 | 10 | 7 |
| Post APT-3 | 25− | 62 | 2.8 | −.02 | 10 | 10 | 3.1 | 6− | 10 |
| Post-strategy | 34 | 58 | 2.4 | 0.2 | 10 | 10 | 2.9 | 10+ | 9 |
| CC | | | | | | | | | |
| Baseline | 22 | 41 | 4.9 | 3.1 | 3 | 9 | 4.1 | 10 | 6 |
| Post APT-3 | 25 | 47 | 4.0+ | 6.6− | 9+ | 10 | 4.8 | 10 | 9 |
| Post-strategy | 28 | 48 | 4.4 | 3.4+ | 6− | 10 | 4.8 | 10 | 10 |

TEA = Test of Everyday Attention. MS1 = Map Search one minute; MS2 = Map Search two minutes; TS = Telephone Search; TSC = Telephone Search While Counting; L = Lottery; VE1 = Visual Elevator Accuracy; VE2 = Visual Elevator Timing; ECD = Elevator Counting with Distraction; ECR = Elevator Counting with Reversal.
+ indicates significant improvement from preceding phase; − indicates significant decrease from preceding phase.

(Zickefoose, Hux, Brown, & Wulf, 2013) or a trade-off of reduced accuracy for increased speed (i.e., AA's performance on Telephone Search).

### *RSAB results*

Participants and a significant other rated everyday attentional behaviour on the RSAB at completion of each phase, see Figure 4(a) and 4(b), respectively. AA rated his attention more positively and BB rated his attention more negatively compared to their respective SOs. CC and his SO generally rated everyday attention as similarly positive throughout the study (with missing data for SO after strategy training). There was minimal change on self-RSAB ratings after either cognitive training intervention.

CC's SO ratings of everyday attentional behaviour remained stable throughout the study. AA's SO rated improvements in speed of thinking, concentration, divided attention and less distractibility after APT-3, with additional improvements after strategy training and follow-up (with the latest effect reportedly due to neuropsychological feedback). In contrast, BB's SO rated significant deterioration in everyday attention after APT-3,

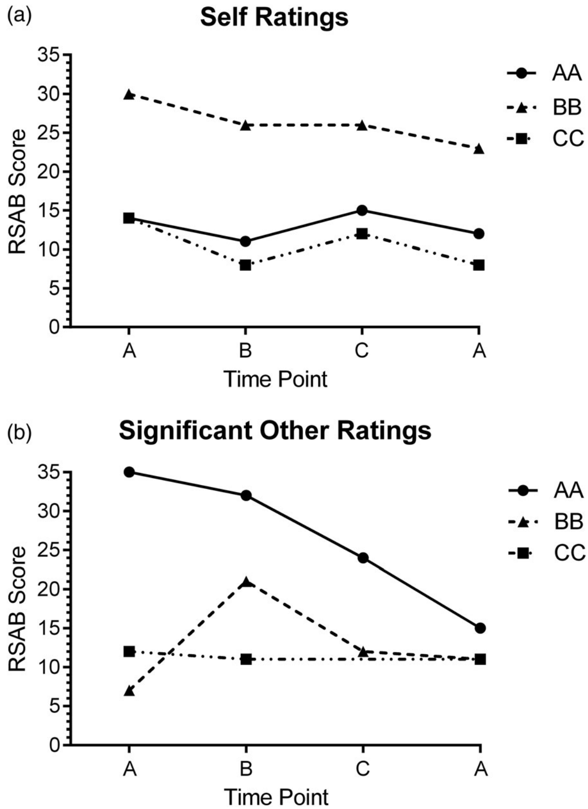


**Figure 4.** Self (a) and significant other (b) ratings of attention on the RSAB. A = baseline; B = APT-3; C = strategy training; A = follow-up.

with higher ratings on physical, verbal and mental slowness, distractibility, difficulty concentrating and divided attention, which improved after strategy training and follow-up.

## Semi-structured interview: Rating scale results

The impressions of participants regarding APT-3 and strategy training are presented in Supplementary Table 1. Participants learned strategies and generally implemented them more frequently in strategy training than during APT-3. Both interventions increased participants' confidence in managing attentional difficulties and minimised their impact in everyday life, although there was limited change in everyday activities.

Participants were generally interested in continuing both interventions with a therapist, whereas one participant (BB) was more willing to continue

APT-3 on his own. Participants generally found both interventions enjoyable. Overall, participants were mostly satisfied with both interventions. Specific feedback about each of the interventions will now be presented.

## Semi-structured interview: Qualitative results

### *Impressions of APT-3*

The most helpful aspects of APT-3 reported by participants centred on brain activation, with BB reporting the computer tasks "stimulated my brain again" and CC saying he felt more "switched on". BB indicated the least helpful aspect of APT-3 was that he had "become so driven" he experienced heightened anxiety, was sleeping less and was more restless during this phase.

### *Impressions of individualised strategy training*

Given the individualised nature of the strategy training, the most helpful and correspondingly most frequently used strategies differed between participants. The most helpful strategies reported by AA were using a diary and creating a daily plan, for BB were attention tones, the prioritisation quadrant and various strategies to cope with anxiety which improved his focus at work, and for CC were aspects of time pressure management, external memory aids, and techniques to remember names. The least helpful strategies cited by AA were self-rewards for attending behaviour and for BB were internal attentional strategies and brain injury education.

### *Choice between APT-3 and individualised strategy training*

When study participants were asked hypothetically to choose between continuing with APT-3 or strategy training, AA and CC chose strategy training whereas BB elected not to choose as he hoped both were beneficial. All participants cited strategy training to be more "relevant" and "applicable" to everyday life and more likely to have "long-term effects" than APT-3. AA and BB reported progress on APT-3 tasks but were unable to identify how improvement had transferred to real-life outcomes.

# DISCUSSION

## The effects of APT-3 and individualised strategy training on outcome measures

In this study, we used an ABCA single-case design repeated across three individuals with severe TBI and attentional or speed deficits to examine the effects of individualised strategy training beyond the effects of computerised training with APT-3, and the subjective experience of these approaches. At the individual level, significant improvements were seen from baseline to APT-3, APT-3 to strategy training, and strategy training to follow-up for two of nine, three of nine and two of nine planned comparisons, respectively. These results suggest minimal change after either intervention on near-transfer measures. Improvements were on SDMT and ASRS, which measure speed of thinking and speed of automatic selective attention. Conversely, no changes were evident on CSRS which measures speed of controlled selective attention. These findings suggest training may improve automatic cognitive processes rather than controlled processes.

### *Factors influencing neuropsychological performance*

The two participants (AA and CC) with poorer baseline attentional performance and greater injury severity (i.e., longer PTA duration) demonstrated greater improvement on outcome measures than BB. Further, AA who was 7 years post-injury, benefited as much from interventions as CC who was 1 year post-injury, suggesting cognitive training may be beneficial in the chronic rehabilitation phase. Zickefoose et al. (2013) also found that individuals with severe attention deficits who were multiple years post-injury benefited from computerised attention training. These findings are unsurprising given individuals with more severe injuries tend to have more severe attentional deficits and more room for improvement (Spikman, Timmerman, van Zomeren, & Deelman, 1999). Motivation, which can also influence gains from cognitive training, appeared to remain high in all study participants.

### *Issues of measuring response to intervention*

Visual analyses demonstrated improvements between baseline, APT-3 and strategy training on the SDMT and cancellation tasks, likely reflecting the large influence of practice effects and potentially spontaneous recovery on reaction time tests. Practice effects were present despite efforts to mitigate these with careful task selection and use of alternate versions, and confounded the measurement of intervention-related change. Many attentional measures considered, including those used to demonstrate efficacy of cognitive training in previous studies, lack adequate test-retest reliability, have significant practice effects or ceiling effects or are too lengthy to be administered repeatedly in a single-case design. This highlights the need to design reliable, brief, but challenging tasks that minimise practice and ceiling effects in order better to assess change following intervention.

Tau-U added greatly to understanding the results by providing a means of controlling for positive baseline (or initial phase) trend to enable exploration of effects beyond practice and spontaneous recovery (Parker et al., 2011).

Two participants continued to improve during follow-up, suggesting that improvement on neuropsychological measures may continue after intervention is complete. Together, these findings highlight the limitations of relying on repeated administration of neuropsychological measures to measure the effects of cognitive training.

## Generalisation

### *Generalisation on an ecological attentional task*

On the TEA, there was considerable individual variability between participants and across tasks with generally equivocal results following both APT-3 and individualised strategy training. No particular domain of attention demonstrated generalisation effects over another. These findings suggest that neither APT-3 nor individualised strategy training generalised consistently to near-transfer neuropsychological tasks.

The TEA was selected as it is an ecologically valid test of the domains trained with APT-3, has adequate to high test-retest reliability and is able to account for practice effects (Robertson et al., 1994). However, the TEA was insensitive to small changes in attentional performance after interventions in this study, particularly for BB who was performing at or close to ceiling during baseline. Practice effects provided in the TEA manual were used to assess significant change present in less than 7% of the population. Perhaps this threshold was too high to detect clinically significant changes in attention, but was used as a means of accounting for practice effects. Zickefoose et al. (2013) similarly found variable and equivocal performances on the TEA within and across individuals following computer training using adjusted scaled scores. Alternatively, gains following cognitive training may take time to work through to significant gains on untrained tests (Holmes, Gathercole, & Dunning, 2009). In this study the TEA was completed immediately after training but not at follow-up as there are only three versions. Results may have differed with further follow-up.

### *Generalisation on rating scales of everyday attentional behaviour*

There were minimal effects of interventions on self-ratings of everyday attentional behaviour on the RSAB, whereas SO ratings were mixed during APT-3 and generally showed improvement during strategy training. These results depict the importance of asking both the participant and an SO to rate everyday attentional behaviour, with ratings either matching closely (CC), or suggestive of better perceptions of performance by the patient (AA) or SO (BB). Variable ratings highlight the challenges of measuring everyday cognitive functioning whereby ratings are influenced by level of cognitive impairment, insight into functioning, exposure to the relevant behaviour and emotional state (Ponsford & Kinsella, 1991). Whilst research has demonstrated improvements over time on attention questionnaires (Ponsford & Kinsella, 1988; Sohlberg et al., 2000), it is unclear whether improvements in ratings of attention were influenced by intervention effects or spontaneous recovery.

## Factors influencing response to interventions

### *Factors influencing the effects of APT-3*

The efficacy of the APT-3 intervention was likely influenced by order of task presentation, tasks administered and length and intensity of treatment. The order of presentation of APT-3 tasks was adaptive and guided by a researcher-generated hierarchy based on complexity, rate of presentation and level of distraction and the protocol was designed to train each domain of attention equally. A different sequence of task administration or choosing tasks to target impaired domains for each participant may have yielded different results. Additionally, participants received nine 1-hour sessions of APT-3 administered in 2–3 sessions per week over 3–4 weeks, which is a similar amount of training to some previous studies (Palmese & Raskin, 2000; Zickefoose et al., 2013) but less than other studies (Park, Proulx, & Towers, 1999; Sohlberg et al., 2000; Tiersky et al., 2005). More numerous, frequent or lengthy training sessions may have improved attentional outcomes. However, research has shown amount of practice was unrelated to improvement on tasks assessing generalisation (Owen et al., 2010) and similar improvement on the PASAT for an APT intervention and control group (Park et al., 1999), casting doubt on the notion that additional training improves attentional outcomes.

### *Factors influencing the effects of individualised strategy training*

Participants whose self-ratings of everyday attentional behaviour were similar (CC) or poorer (BB) than their SO, suggesting good awareness, were more likely to implement strategies in their everyday lives than AA, who rated his everyday attentional behaviour better than did his SO. AA failed to appreciate the impact of attentional difficulties on his everyday functioning, infrequently completed homework tasks and required much prompting and reinforcement to implement new strategies during the strategy training phase. Building awareness may be a necessary precursor to successful strategy training, whilst being aware of the potential negative effects of raising awareness on mood (Sasse et al., 2013). Other approaches may include involving an SO or manager in goal setting and implementation of strategies, or restructuring the environment or tasks to improve everyday attentional behaviour (Sloan & Ponsford, 2013).

## Qualitative observations of interventions

Both interventions were well tolerated and improved confidence in managing attentional difficulties in everyday life, although there was limited change in daily activities after the interventions. As expected, participants reported strategy training to be more helpful than APT-3 in improving everyday strategy use. Caution and monitoring for adverse effects during the use of computer training is appropriate, particularly for highly driven individuals, as BB noted heightened anxiety during APT-3 whereby he became "driven", reporting elevated heart rate, restlessness and sleeping less, and his SO rated deterioration in his everyday attentional behaviour during this phase.

## Preferences for APT-3 vs. individualised strategy training

Two of three participants outlined a preference for strategy training over computer training, with the third participant electing not to choose, hoping both interventions would be effective. All participants perceived strategy training to be more "relevant" and "applicable" to everyday life and more likely to have long-term effects than APT-3, a finding that is consistent with previous research (Zickefoose et al., 2013). The preference for strategy training over computer training likely reflects the smaller transfer distance between training tasks and activities in daily life (Clark-Wilson, Giles, & Baxter, 2014).

## Individual variability across participants: Enhancing rehabilitation outcomes

There was considerable variability between participants' cognitive functioning, daily-life demands and hence goals, necessitating individualised strategies and varying approaches to rehabilitation. This study highlights the need for rehabilitation to be client-centred and driven by individual goals in order to be meaningful and effective in improving outcomes (Grant, Ponsford, & Bennett, 2012; Sloan et al., 2009).

It has been recommended that computer training be used in conjunction with metacognitive strategy training and self-regulation support (Sohlberg & Mateer, 2010) and with therapist involvement to assist generalisability (Cicerone et al., 2011). In this study, participants indicated they received greatest benefit from strategies applicable to their everyday attentional goals (i.e., diary use, prioritisation quadrant and attentional strategies for recalling names) which are not particularly amenable to rehearsal in conjunction with computer training. Thus, clinicians should consider each individual's goals and select the most appropriate metacognitive strategy training applied to everyday difficulties, rather than necessarily combining it with a computer training programme (Park & Ingles, 2001; Ponsford et al., 2014).

Further, whilst participants were recruited on the basis of reduced speed of information processing or attentional difficulties they also demonstrated difficulties with memory, executive functioning, mood and fatigue. Individualised strategies were provided in these areas as such impairments interplayed with attentional difficulties (Ponsford et al., 2014). Given the heterogeneity of cognitive impairments associated with TBI it may not be appropriate to focus on individual cognitive domains when designing and evaluating interventions.

### Limitations and future directions

We acknowledge this study included only three cases and therefore significant conclusions cannot be drawn regarding the efficacy of APT-3 compared to individualised strategy training in individuals with TBI. It is possible that gains after the individualised strategy training were the result of additive effects of both cognitive training approaches, rather than representing a unique contribution of individualised strategy training beyond APT-3. Further, a client-centred approach was taken in the individualised strategy training phase incorporating a variety of rehabilitation techniques across participants and thus it is unclear which components of the intervention influenced the current findings. GAS ratings may be subject to rater bias as they were completed by non-blinded patient and therapist in cooperation and should be interpreted cautiously. Further, GAS and semi-structured interviews were conducted upon completion of each phase, potentially not allowing for sufficient time for participants to experience intervention-related changes. Change in CC's diplopia and motor weakness throughout the study may have influenced his performance on outcome measures, although with regard to motor impairment he demonstrated improvement on oral SDMT as well as the cancellation tasks. The implementation of strategy training and computer-based remediation of attention is an area that requires further investigation. Delivery of metacognitive strategy training in a group setting or via web-based platforms will allow for the investigation of cost effectiveness and efficacy in such contexts.

## CONCLUSIONS

This single-case series demonstrated that assessing an individual's goals and implementing individualised strategy training after TBI resulted in improvement on tests of attention and generalisation to SO ratings of everyday attentional behaviour beyond the effects of computerised training. Individualised strategy training was also generally preferred by participants relative to APT-3. Neither intervention demonstrated significant generalisation on neuropsychological measures or self-rating scales of everyday attention. Given the considerable variability in attentional deficits and everyday attentional requirements between individuals, therapy to remediate attentional deficits was most beneficial when designed to address patient-centred goals using individualised strategies, tailored approaches to rehabilitation and incorporating additional strategies for memory, executive functioning, mood and fatigue difficulties. Further research is required to confirm these findings in larger samples, using more reliable outcome measures. This study highlights the need for individualised rehabilitation of attention in order to improve everyday functioning and facilitate meaningful outcomes following TBI.

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