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Selective Training of Theory of Mind in Traumatic Brain Injury: A Series of Single Subject Training Studies

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Abstract: *Primary Objective:* To examine the potential for treating deficits in Theory of Mind (ToM), i.e., using a person's beliefs to understand and predict behaviour, and to test the hypothesis that improvements in ToM can be distinguished from performance in other domains such as judging line orientation and executive function.

Materials and Methodology: In Study 1, two individuals with TBI participated in a protocol targeting ToM, which was assessed using a cartoon interpretation task. Participants also performed on a short form of the Benton Judgment of Line Orientation Task as a control. In Study 2, a third person with TBI participated in Attention Process Training (APT-1) followed by the ToM protocol. Executive function was assessed using the Paced Auditory Serial Addition Task (PASAT).

Results: In Study 1, ToM performance but not judgments of line orientation responded to the ToM training. In Study 2, executive function, but not ToM, showed strong improvement with APT-1. In contrast, ToM but not executive function showed significant improvement with ToM training.

Conclusion: ToM is a good candidate for intervention. For three persons with TBI, ToM performance showed selective improvement associated with ToM treatment, which suggests a practical as well as theoretical value for distinguishing ToM from executive function.

Keywords: Attention, cognitive rehabilitation, executive function, social communication, theory of mind, traumatic brain injury.

INTRODUCTION

Many persons with traumatic brain injury (TBI) exhibit debilitating cognitive and communication impairments [1-11]. The language-related symptoms often fall outside the traditional definition of aphasia and include difficulty understanding a speaker's goals in a conversation and how an utterance serves those goals. Impairment in these areas can leave a person unable to appreciate fully, for example, sarcasm, deception, and some forms of humour, all of which are common and important features of natural conversation occurring in work and social contexts. A current organizational framework for analysing these aspects of communication is termed Theory of Mind (ToM), the ability to use other people's beliefs to understand or predict behaviour [12-14]. In this paper, we start from the theoretical position that ToM is a distinct domain of cognition [13] and then describe work with three individuals with TBI to test the usefulness of a training program that specifically targets ToM.

The following scenario illustrates components of ToM and how ToM performance draws on a range of cognitive abilities. While at work, Jim spends 45 minutes talking with a friend and, as a result, is late for a meeting with his boss and co-workers. People already at the meeting have no direct access to the reason for Jim's lateness; their *first-order beliefs* about the situation are incomplete or incorrect. Jim could tell them the literal truth (that he lost track of time while talking to a friend). Alternatively, he could save face by lying: 'I was delayed by a call from an important client.' Use of intentional deception rests on the speaker's (Jim's) *second-order beliefs*, i.e., what he believes about listeners' beliefs. Jim might attempt a lie if he thinks that his listeners do not know the real reason for his tardiness. However, a co-worker Sally left the meeting to retrieve a file and, unbeknownst to Jim, overheard Jim's conversation with his friend. Sally returned to the meeting before Jim and told the others the real reason for Jim's absence, thereby correcting their first-order beliefs. When Jim finally enters the meeting, he may attempt using a lie based on his false second-order belief. Of course, Jim's attempted deception would fail and would result in increased rather than decreased embarrassment. On the other hand, if Jim realizes that his listeners know the truth, he may still say 'I was delayed by a call from an important client,' but as an attempt to use ironic humor to defuse an awkward situation rather than as an attempt to deceive. People at the meeting need ToM to understand the intended meaning of true or untrue utterances spoken by Jim.

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A common method of assessing ToM requires observers to interpret false-belief scenarios analogous to the example above, which typically involve characters whose conflicting beliefs and access to objective truth must be remembered, updated, and compared. Also, observers must inhibit responding on the basis of objective truth when explaining the behaviour of a misinformed character. The structural complexity of ToM scenarios and the need to inhibit responses based on what an observer knows to be true suggest one theoretical perspective: that performance on ToM tasks in large part depends on resources shared with executive function [15-18].

Brain-based studies confirm an association between ToM and executive function. Frontal and prefrontal system involvement, characteristic of the population of individuals with TBI, has often been linked to disrupted executive function [19-22] and ToM [23]. In addition, functional imaging studies of neurotypical adults similarly suggest overlap between brain regions activated during executive function and ToM tasks [24, 25]. Finally, Tompkins and colleagues [26] compared the performance of individuals with right hemisphere brain damage (RHD) on second-order belief scenarios [27] to carefully constructed, equivalent passages that did not require ToM processing. Their finding was that controlling the complexity of stimulus passages, that is, controlling the demands placed on executive function, eliminated any selective ToM impairment. In sum, a large body of behavioural and neurological data document the connection between ToM and executive function and, accordingly, raise the question whether the ToM construct adds anything to our understanding of, and treatment of, impaired communication.

Although performance on some ToM tasks can be explained in terms of more general constructs such as executive function, there is, nonetheless, considerable evidence for an opposing view that ToM capacity and executive function are usefully distinguished. Saxe and her colleagues have used functional imaging studies with neurologically intact adults to identify temporo-parietal regions as particularly relevant for processing mental states when stimulus complexity, i.e., executive function demands, are well controlled [28-30]. Griffin *et al.* [31], Happé *et al.* [32], and Lundgren and Brownell [33] report selective ToM impairments in patients with RHD, using cartoon interpretation tasks that reduced working memory demands. Finally, Muller and colleagues [9] found no significant correlation between components of executive processing and ToM abilities in a group of individuals with severe TBI who performed worse than controls on a set of verbal and non-verbal ToM tasks.

The hypothesized dissociation between ToM and executive function impairment in people with TBI, as well as in individuals with brain-damage due to other etiologies, provides context for the main empirical questions addressed here: is there potential value to treating ToM separately in individuals with TBI, and can ToM be improved by training directed at components of executive function? The ToM training program uses visual support to reduce working memory demands and incorporates practice evaluating, updating, and comparing mental states. (See Lundgren and Brownell [33] for a description of the protocol and results from a patient with RHD.) In this paper, we focus on individuals with TBI and report a pair of studies using variants of a multiple baseline, single subject experimental design [34-36] to evaluate this phase II treatment project [37, 38].

In Study 1, two individuals with TBI were enrolled in the ToM protocol. Their performances were repeatedly assessed using two measures. The first was a Cartoon Interpretation task that used cartoons selected from Gary Larson's The Far Side [39] whose ‘meaning’ or humour relies on first-order beliefs (a character’s ignorance about reality) or second-order beliefs (one character’s deceiving another character). During each session, the participant interpreted 2 first-order and 2 second-order belief items. The participant was asked to identify salient features in the picture, read the caption, and, finally, describe what most people would find amusing. It was not important that the participant judged the cartoon to be funny, but that he understood what most people would identify as being humorous. A 0-6 scale for scoring quality of Cartoon Interpretations (inter-rater reliability = 90%) [40] was used to evaluate the individual’s performance. Three judges rated each interpretation and then resolved any discrepancies *via* discussion.

The second dependent measure, also obtained at each session, was a short form of the Benton Judgment of Line Orientation Task [41]. In this visuo-spatial task, a line segment at an angle is presented and then removed from view. The examinee then selects a line segment with a matching orientation from an array of choices. As a control task that was not treated, judgment of line orientation was not expected to change. Thus, the main hypothesis tested in Study 1 was that training ToM would improve performance in this domain selectively, that is, that performance on ToM would improve while visuospatial performance would not.

Study 2 examined the value of ToM training over and above prior training that involved working memory, inhibition, and attention -- all key components of executive function that are plausibly required for good performance in many ToM paradigms and that are often impaired in persons with TBI. In Study 2, we enrolled a third individual with TBI to again explore the potential for training ToM. We are not hypothesizing a total separation of ToM from executive function. Instead, we test that there is enough separation between ToM and executive function to justify evaluating and treating ToM separately.

For the training phase, we used a slightly modified version of the Attention Training Program (APT-1) [42] which is effective for treating attention deficits in adults with TBI [43-47]. This multilevel treatment program targets selective, sustained, divided and alternating attention along a continuum of easiest to most difficult. Our modifications to Sohlberg and Mateer’s APT-1 protocol included reducing the number of sessions taken to administer this program to 10.

For assessing change in executive function, we used Gronwall’s Paced Auditory Serial Addition Task (PASAT), which requires sustained attention, inhibition, and working memory [48-50]. In PASAT, the participant listens to single digits presented every 3 seconds on an audio CD. (There is also a 2-second version that was not used). The task is adding the two last digits heard and reporting the sum: if the first two digits were 6 and 7, the participant would respond 'thirteen'; if the third digit was 4, the participant would then respond 'eleven', and so on. The maximum score is 60 (based on 61 presented digits). While PASAT performance is sensitive to practice effects, these are described as greatest in the first few administrations [50].

In sum, we report results from two studies that test the efficacy of a ToM protocol that uses visual support and provides practice with mental states. In Study 1, we contrast ToM performance with visuospatial ability. In Study 2 we distinguish gains in ToM from gains associated with previous training with elements of executive function.

MATERIALS AND METHODOLOGY

Participants

Three individuals with TBI were recruited to participate. All three satisfied the following criteria: moderate to severe TBI defined by the Glasgow Coma Scale (GCS) immediately following injury; geographical proximity to testers; no report of significant drug or alcohol use, prior neurologic or psychiatric illness, dysarthria or aphasia, or pre-existing learning disability; no report of impaired (uncorrected) hearing or vision; completion of high school; and having grown up using American English. All three presented with reduced interpersonal and conversational skills, although this clinical judgment was not documented with formal testing. All signed an IRB-approved consent form. All had been discharged from any cognitive rehabilitation programs prior to enrolment. See Table **1** for additional description of the participants, including targeted cognitive-linguistic testing.

Study 1. One individual with TBI, S01, was a 58-year-old man two years post injury due to a motorcycle accident. His TBI was initially classified as severe (GCS = 3). A second person with TBI, S02, was a 27-year-old man three years post injury due to a motor vehicle accident. His TBI was also initially classified as severe (GCS = 4).

Study 2. A third person with TBI, S03, was a 25-year-old man one-year post injury due to a motor vehicle accident. His TBI was initially classified as severe (GCS = 4).

Procedures

Study 1. Two primary dependent measures in Study 1, Cartoon Interpretation and Line Orientation, were obtained at all sessions--during the initial baseline, during training, and after training had ceased.

Protocol Description

Pre-training Baseline (Sessions 1-10, 3 per week for approximately 3 weeks): Each session included assessment of Cartoon Interpretation and Line Orientation (10 data points for each dependent measure).

ToM Training (Sessions 11 – 19 for S01, 11-20 for S02, 3 per week for approximately 3.5 weeks): Each one-hour training session included ToM training plus assessment of Cartoon Interpretation and Line Orientation tasks (approximately 10 data points for each dependent measure).

Post-training Baseline (Sessions 20-29 for S01, 21-30 for S02, 3 per week): Each session included assessment of Cartoon Interpretation and Line Orientation (10 data points for each dependent measure).

The ToM Training Program [33] entails extensive practice with mental state operations that require (1) generating thoughts about pictured objects from another's perspective; (2) evaluating one or two characters' beliefs (true or false) as objects change form and as the characters change location within a depicted house, thereby changing their perceptual access to updated information; (3) evaluating differences between characters' beliefs; and (4) inhibiting personalized thoughts unrelated to the characters. Our training program uses visual support (e.g., a cut away drawing of a house with different rooms in which different characters can be located) to support multiple opportunities for a participant to practice, correct, and learn skills necessary to progress from one phase of the training program to another. Training begins with the Warm-Up Phase and is followed by four distinct training phases that start with first-order beliefs and progress to include second-order beliefs, including intentional deception. Different participants progress through the training at different rates and require varying numbers of sessions.

Study 2. Used a more complex design. Two primary dependent measures were obtained in Study 2 in each of 48 sessions-during the initial baseline, during both trainings, and when no training was administered. The first was the score on Cartoon Interpretation. One difference in this measure from Study 1 is that in Study 2, S03 was asked to interpret only one first-order item and one second-order item for each assessment in order to leave sufficient cartoons for the greater number of assessments administered in Study 2. The second dependent measure was the PASAT.

Protocol Description

Pre-training Baseline (Sessions 1-7, three per week for approximately 2.5 weeks): Each session included assessment of Cartoon Interpretation and PASAT (7 data points for each dependent measure).

APT-1 Training (Sessions 8-17, 3 per week for approximately 3.5 weeks during APT-1): Each training session included APT-1 training plus assessment of Cartoon Interpretation and PASAT (10 data points for each dependent measure).

Post-APT-1 Training Baseline (Sessions 18-31, 3 per week): Each session included assessment of Cartoon Interpretation and PASAT (14 data points for each dependent measure) with no training.

ToM Training (Sessions 32-41, 3 per week): Each session included ToM training plus assessment of Cartoon Interpretation and PASAT (10 data points for each dependent measure).

Post-ToM Training (Sessions 42-48, 3 per week): Each session included assessment of Cartoon Interpretation and PASAT (7 data points for each dependent measure) with no training.

Table 1. Participant data.

Participant	S01	S02	S03
Age	58	27	24
Years of education	16	14	13
Time Post Onset (years)	2	3	1
Gender	Male	Male	Male
Race	White	White	White
Vocation Pre injury Post injury	Administrator in a large international company Volunteer in a hospital	Police Officer Unemployed	College Student Unemployed
Initial Glasgow Coma Scale Score	3	4	4
Communication/cognitive features	Verbose, tangential, impulsive	Poor initiation, flat affect, difficulty reading social cues	Poor initiation, flat affect
Test of Everyday Attention [51] Scaled Scores (M=10) Map Search (SD=2.6) Elevator Counting with Distractions (SD=2.3) Visual Elevator (SD=2.4) Elevator Counting with Reversal (SD=2.1) Telephone Search while Counting (SD=2.6) Lottery (SD=2.46)			Pre/Post APT 6/7 7/12 5/7 3/7 6/15 1/5
Delis-Kaplan Executive Function System [52] Scaled Score (M=10; SD=3) Color-Word Interference Test *Inhibition/Switching*	Pre/Post 7/12	Pre/Post 10/12	Pre/Post 4/7
Cognitive-Linguistic Quick Test [53] (*Used to screen language skills prior to training.*) Cognitive Domain of Language: Personal Facts Confrontation Naming Story Retell Generative Naming	Score/Severity Rating 31(WNL)	Score/Severity Rating 34(WNL)	Score/Severity Rating 27(Mild)

RESULTS

Overview of Analysis

We rely on statistical as well as visual evidence to evaluate training effects [54]. How large a change in performance occurred is expressed using Cohen's d defined as:

$d = (\text{Mean}_{\text{Post initiation of treatment}} - \text{Mean}_{\text{Pre-Treatment Baseline}}) / \text{SD}_{\text{Pre-Treatment Baseline}}$.

Effect size calculated in this way provides a conservative index because the post initiation of training mean includes data from training sessions during which performance changes most rapidly: 'post training' means would generally be higher if based only on sessions taking place after training had ceased. The conservative definition of effect size is used to be consistent with the division of sessions (pre- versus post-initiation of training) used for the inferential analyses presented below. In Study 2 we augment the basic results by presenting an alternative, less conservative effect size that excludes data from training sessions during which performance was changing most rapidly. These supplementary results highlight differences in Baseline performance (prior to any training) and performance after completion of training.

While effect sizes for single subject investigations of ToM are hard to interpret without context provided by other treatment studies for ToM, Beeson and Robey and others [55, 56] have suggested the following benchmarks for single subject studies of aphasia treatments: small = 2.6, medium = 3.9, and large = 5.8. These guidelines are quite different from those often cited for group studies, for which a Cohen's d of .8 or higher is considered 'large.'

We evaluate the statistical significance of training effects using correlational analysis and a combination of bootstrapping and simulation (Simulation Modeling Analysis or SMA) recently outlined by Borckardt *et al.* [57]. All Baseline, Pre-initiation of training sessions were coded as 0, and all post-initiation of training sessions (during and after training) were coded as 1. The dependent variables were Cartoon Interpretation score and Line orientation score (in Study 1) or Cartoon Interpretation and PASAT (in Study 2). The point biserial correlation between Pre- versus Post-initiation of training and performance provides the starting point. However, this correlation conflates improvement coincident with the start of training with any other factors that might exert effects across all sessions independent of training: e.g., gradual improvement due to practice, familiarity with assessment measures, spontaneous recovery, benefits of social stimulation, etc. In order to test the statistical significance of a training effect apart from other, nonspecific factors, the Borckardt *et al.* [57] SMA avoids the problems interpreting p values from conventional procedures (regression, analysis of variance) applied to data from a single subject [58]. Rather than compare differences in mean performance using a conventional error term based on non independent observations, the software starts by calculating the degree to which a response from a single person depends on what the person responded on the previous session (the lag 1 autocorrelation) across all sessions before, during, and after training. The autocorrelation provides an index of steady change across the entire set of sessions. The SMA software then generates thousands of simulated data sets with the same autocorrelation to provide a statistical context for what would happen under the null hypothesis of steady change across all sessions without any specific training effect. The critical step for establishing statistical significance is comparing the obtained data that includes a training effect as well as steady change against the set of null hypothesis simulation samples. The question is whether the obtained difference between before and after the start of training is greater than the difference found in 95% of the null hypothesis simulations that represent what to expect just on the basis of practice. In sum, this analysis takes into consideration both gradual improvement due to practice and also the variability that is so common in brain injured performance, which makes the traditional requirement for a stable baseline prior to initiation of treatment less critical. The test of statistical significance also takes into consideration any autocorrelation across data points from a single individual.

The Borckardt *et al.* [57] SMA works best with a minimum of approximately 20 sessions. In Study 1 we *a priori* decided to administer 10 Baseline sessions to each participant to insure sufficient data points both pre- as well as post-initiation of training. (Study 2 was longer overall.) The high, fixed number of sessions prior to the start of training did not detract from participants' willingness to complete the protocol.

To supplement the statistical evaluation, we also present graphs for which each participant's Cartoon Interpretation scores across all sessions were converted to z score form, as were his line orientation scores (in Study 1) or PASAT scores (in Study 2). These transformations equate the variability of different dependent measures, which facilitates comparisons of changes in performance across dependent measures and (in Study 2) across training protocols. Finally, we present values for the Coefficient of Variation to express how variable scores are in a form that allows comparison across participants and across studies. The Coefficient of Variation is defined as (SD / Mean) x 100 [59].

Study 1. Figs. (**1** and **2**) and Table **2** show the scores for Cartoon Interpretation and Benton Line Orientation Task for S01 and S02, respectively, across all sessions in the study.

For S01, Table **2** and Fig. (**2**) show that his Cartoon Interpretation improved after initiation of ToM training in Session 11, while his Line orientation performance did not. The effect sizes were quite different (d = +3.99 for Cartoon Interpretation and d = -.26 indicating slightly worse performance over sessions for line orientation).

For S01, the correlation between Pre versus Post-Initiation of Training and Cartoon performance, r = +.80, was significant, p = .03 (according to the Borckardt *et al.* [57] SMA), which supports the existence effect of treatment that is distinct from general improvement due to practice, as shown in Fig. (**1**). In contrast, line orientation performance showed no hint of improvement attributable to some effect specific to the ToM training (r = -.13, p = .47). All told, there is good evidence for improvement in ToM performance that can reasonably be linked to the training.

S02 similarly showed good evidence for a selective effect of ToM training. His effect size for Cartoon Interpretation was d = +4.80, while his effect size for Line orientation was very small, d = -.49. The r value for the Pre versus Post-Initiation of training and Cartoon Interpretation was strong, r = +.86 and significant (p < .01) even in the context of steady improvement across sessions as illustrated in Fig. (**2**). There was no hint of an effect in Line Orientation, r = -.20, p = .48, as shown in Fig. (**2**). S02 thus provides additional evidence for a selective ToM training effect.

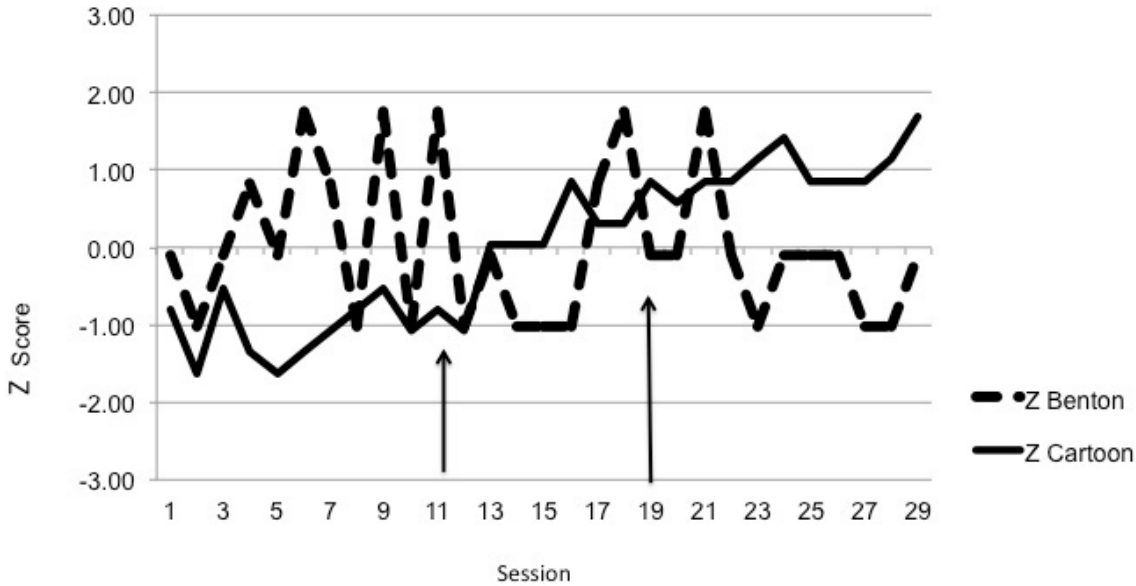

Fig. (1). Responses from S01 (Study 1) for cartoon interpretation (solid line) and judgments of line orientation (dashed line). Arrows indicate the beginning and end of Theory of Mind treatment sessions.

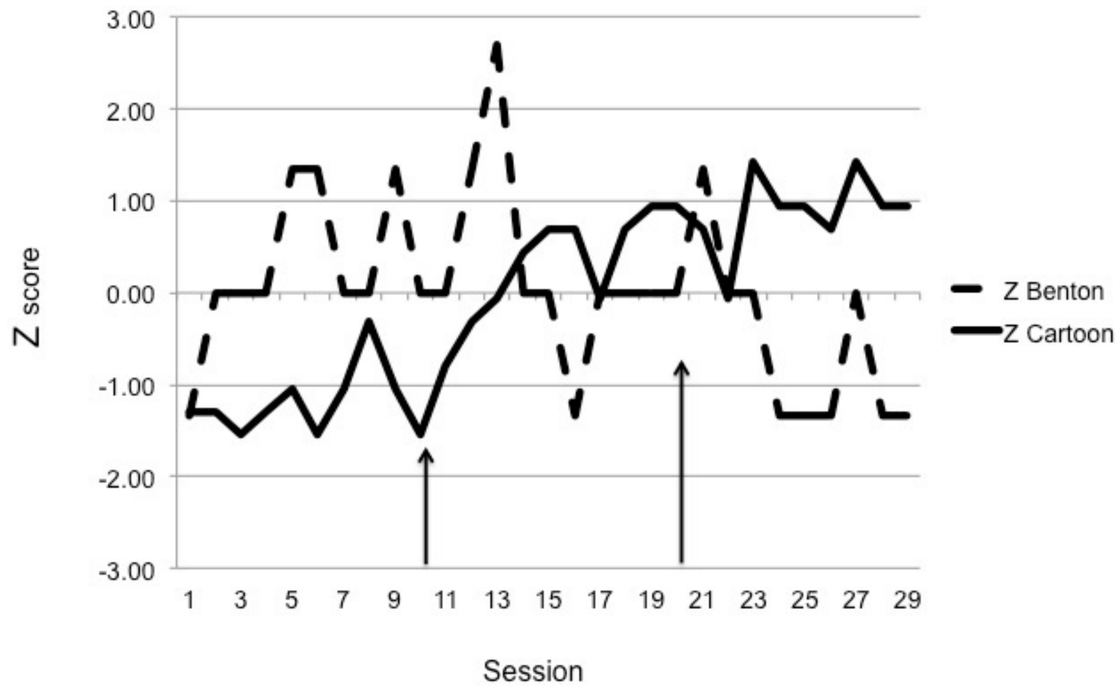

Fig. (2). Responses from S02 (Study 1) for cartoon interpretation (solid line) and judgments of line orientation (dashed line). Arrows indicate the beginning and end of Theory of Mind treatment sessions.

Table 2. Results for ToM training (Study 1).

S01 **ToM Training: Cartoon Interpretation Task**			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	9.0	14.95	3.99
Standard Deviation (SD)	1.49	2.53	
Coefficient of Variation	16.56	16.92	

Table 2. contd…

S01 ToM Training: Line Orientation Task			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	13.30	13.00	- 0.26
Standard Deviation (SD)	1.16	1.05	
Coefficient of Variation	8.72	8.08	
S02 ToM Training: Cartoon Interpretation Task			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	8.40	15.65	4.80
Standard Deviation (SD)	1.51	2.32	
Coefficient of Variation	17.98	14.82	
S02 ToM Training: Line Orientation Task			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	12.20	11.90	- 0.48
Standard Deviation (SD)	0.63	0.79	
Coefficient of Variation	5.16	6.64	

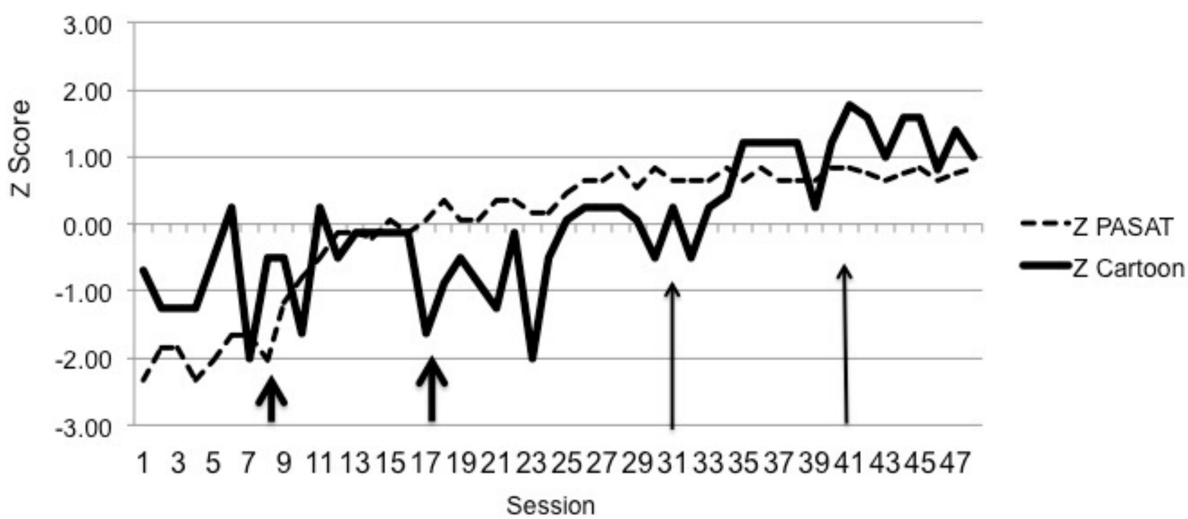

Fig. (3). Responses from S03 (Study 2) for cartoon interpretation (solid line) and judgments of line orientation (dashed line). Thick arrows indicate the beginning and end of attention process training, and thin arrows indicate the beginning and end of Theory of Mind training.

Study 2.

Attention Processing Training (APT-1). Fig. (**3**) shows S03's scores for PASAT and Cartoon Interpretation across the 48 sessions in the entire study. Results are summarized in Table **3**.

This individual showed evidence of an effect specific to the APT-1 training over and above a steady increase over sessions, which was also present. First, we calculated correlations using pre- (Sessions 1 – 7) versus post-initiation of training assessments (Sessions 8 – 31) for both PASAT and Cartoon Interpretation score. (Recall ToM training began at Session 32.) There was clear improvement in PASAT performance: r= +.82, p = .01; PASAT effect size: d = +7.05. There was less evidence for change in the Cartoon scores associated with the initiation of APT-1: r = +.32, p = .10, effect size: d = +.72. This portion of the study is consistent with an effect of APT-1 on executive function as measured by the PASAT.

Theory of Mind Training. ToM training was associated with slight, not quite significant, additional improvement on PASAT. Pre ToM training performance was based on data from Session 18 (just after APT-1 training ceased) through

Table 3. Results for ToM training and APT-1 training (Study 2).

S03 APT-1 TRAINING: Cartoon Interpretation Task			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	1.39	2.08	+.72
Standard Deviation (SD)	0.96	0.86	
Coefficient of Variation	69.06	41.35	
S03 APT-1 TRAINING: PASAT			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	20.86	41.79	+7.05
Standard Deviation (SD)	2.97	6.90	
Coefficient of Variation	14.24	16.51	
S03 ToM TRAINING: Cartoon Interpretation Task			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	1.93	4.00	+2.25
Standard Deviation (SD)	0.92	0.79	
Coefficient of Variation	47.67	19.75	
S03 ToM TRAINING: PASAT			
	Pre Training Baseline	**Post Initiation of Training**	**Cohen's d:[Post-Pre]/SDPre**
Mean	45.86	48.88	+1.10
Standard Deviation (SD)	2.74	0.93	
Coefficient of Variation	5.97	1.90	

Session 31. ToM training started in Session 32 and continued through Session 41. PASAT effect size was relatively small, $d = +1.10$. The point biserial correlation was $r = +.62$, $p = .11$. Fig. (**3**) further suggests some steady linear improvement unrelated to treatment.

In contrast, ToM training was associated with significant improvement on Cartoon Interpretation. The ToM effect size based on the comparison between sessions immediately after the end of APT but before the start of ToM training (i.e., Session 18 – Session 31, inclusive) and the post initiation of training mean (i.e., Sessions 32-48) was larger, $d = +2.07$, and the point biserial correlation was significant, $r = +.75$, $p < .01$. We then repeated the Borckardt *et al.* [57] SMA using data from all sessions up until the start of ToM training (i.e., Sessions 1 through 31 rather than just Sessions 18 – 31) because no ToM training was administered during Sessions 1 - 31. The analysis comparing Sessions 1 – 31 to Sessions 32 – 48 yielded virtually identical simulation results in support of an independent effect of training: $r = +.76$, $p < .01$. These results lend additional evidence in favour of ToM as a distinct cognitive domain.

An alternative, less conservative evaluation rests on a comparison that excludes data from training sessions because performance changed markedly during training phases. Sessions 25 – 31 were devoid of any training. When the Cartoon Interpretation mean for these 7 sessions was compared to the Cartoon Interpretation mean for Sessions 41-48 during which there was similarly no training, the effect size increased to a moderate size, $d = +4.3$.

DISCUSSION

These two studies provide preliminary evidence for the selective impact of a ToM training protocol for individuals with TBI [33]. Study 1 showed that improvement on a ToM measure can dissociate from a measure of performance in the visuospatial domain and yielded effect sizes that might be tentatively characterized as 'medium' [55, 56]. Study 2 presented additional evidence that ToM training was associated with a significant impact on the ToM performance beyond any gains associated with prior training (APT-1) directed at executive function or practice. These results confirm that there is a degree of functional and clinically relevant dissociation between ToM performance and aspects of visual perception or executive function. The implication is that domain-specific treatment can provide measurable impact on ToM for some individuals with TBI. More generally, these results highlight the potential for treating deficits in social cognition and discourse level communication.

There are many limitations to the present study. Most important is that the scope of generalization of treatment gains is not yet defined. The Cartoon Interpretation task is itself dissimilar to the training materials and thus documents some degree of generalization, but the ultimate test will be a person's success in naturally occurring social situations. We also need to consider the immediate practical issue of how well the ToM training protocol will work with other individuals, male or female, who vary in terms of severity of impairment and in symptom profile.

Our results add to the body of findings on the status of ToM within a general theory of cognition, but raise a number of conceptual issues. The findings reported are consistent with the studies by Saxe and colleagues [29, 30] that show that is possible to dissociate ToM from other cognitive domains under the right conditions. However, our findings in Study 2 also confirm the need for careful consideration of potential overlap between ToM and executive function [e. g., 26]: although the effect was statistically weak, this one individual displayed a hint of improvement (d = +.72) in ToM associated with APT-1. Other individuals with TBI may show stronger improvement in ToM coincident with APT-1 or equivalent training that targets executive function. ToM performance can in principle dissociate from executive function, but ToM performance can also overlap to varying degrees with executive function.

In Study 2, we chose a conservative approach to testing the efficacy of ToM training by administering the APT-1 first. Our goal was to test whether ToM performance can benefit from separate treatment, even after a person has experienced training and assessment of executive function using APT-1 and the PASAT, which does not require understanding or manipulating mental states. Our results are consistent with the view that ToM is a distinct cognitive domain that should be targeted for treatment at least in some individuals. However, the design of Study 2 does not support evaluation of possible carryover effects between the APT-1 and ToM protocols. Because ToM training provides practice and feedback applying assorted cognitive skills (e.g., updating, inhibition) in addition to practice monitoring beliefs, administering ToM training first might well lead to substantial improvement on PASAT as well as on Cartoon Interpretation. It is also logically possible that the effectiveness of ToM training could be enhanced by prior exposure to APT-1. Again, our main point is the potential value of treating ToM. We leave for future research the question of exactly how the sequence of these two protocols affects treatment gains. This is a difficult question because the degree of overlap between processing limitations affecting the two domains and protocols will vary from person to person.

ToM, as studied here, may also be relevant to other cognitive tasks, such as distinguishing accidental from intentional harm [60, 61] and distinguishing intentional from unintentional violation of social norms [62]. The exciting possibility is that training ToM may affect performance in selected social cognitive domains and thereby increase the usefulness of intervention.

A last point concerns a connection between APT-1 and executive function during the beginning sessions of Study 2. The literature is mixed on whether benefits of APT-1 extend beyond attention and whether APT-1 ought to be used to treat executive dysfunction [47]. Our view is that PASAT provides an index of executive function, and that our data are at least consistent with the view that APT-1 can impact executive function under some conditions.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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