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Procedural discourse performance in adults with severe traumatic brain injury at 3 and 6 months post injury

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Abstract

Background: There is limited research on communicative recovery during the early stages after a severe traumatic brain injury (TBI) in adults.

Methods and procedures: In the current study 43 people with severe TBI described a simple procedure at 3 and 6 months post injury and this was compared to the description provided by 37 healthy speakers. Linguistic productivity and the presence of macrostructural discourse elements were analysed.

Main outcomes and results: No change occurred in productivity in the TBI group between the two time points. There was increased use of relevant information (macrostructure) over time for the TBI group, reflecting improvement. People with TBI differed from controls in speech rate and in two out of three macrostructural categories at both time points, indicating difficulties even after 12 weeks of recovery.

Conclusions: Overall, the quality, rather than the quantity of discourse was disordered for participants with TBI. Findings indicate that procedural discourse is sensitive to discourse deficits of people with TBI and can be used to map recovery during the sub-acute phase.

Keywords

Linguistic productivity; macrostructure; communication; recovery; follow-up; discourse

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Declaration of Interest
The authors report no declarations of interest.

Introduction

Traumatic brain injury (TBI) is a significant problem in both the developed and developing countries, which results in lifelong rehabilitation and medical costs to society [1,2]. Between 100 and 200 people per 100,000 annually suffer a head trauma in the Western countries [3,2] and it has been estimated that a little more than 6 million people experience impairments following TBI in Europe [2]. Yearly in the USA, roughly 1.2 million people receive emergency care, almost 300 000 are hospitalized and 50 000 die following TBI [4]. Furthermore, approximately 3.2 million people experience disabilities following TBI in the USA [1].

Communication disorders arising from severe TBI may include dysarthria, aphasia and cognitive communication disorders. Dysarthria has been reported for about 30% of the TBI population [5] and appears to persist over time [5,6]. Aphasia has been reported for about 2% [53]–19% of the people with TBI [5]. Aphasic symptoms are generally present in the early stages of recovery and a greater improvement is seen in aphasia compared to dysarthria [5,6]. Although a majority of people with severe TBI score normally on aphasia tests [7,8], research has shown that they perform worse on subtests assessing word finding abilities, verbal fluency and complex comprehension tasks compared to controls [9,10]. However, impairments in such specific language functions do not reflect the deviant communication behaviour seen in people with severe brain injuries [11]. People with severe TBI have a disorder of language use (i.e., pragmatics), rather than with the form language takes at word and sentence level [12].

It has been established that the deficits in severe TBI are not of the aphasic type [7,8] and that conventional aphasia batteries do not clearly delineate the communication difficulties in this population [13]. The term '*cognitive communication deficit*' [14] is often used today to define the communicative deficits that are present in people with TBI. The term demonstrates the relationship between the communicative impairments and the underlying mechanisms causing them. A cognitive communication disorder in severe TBI may be manifested as lack of information provided for a topic [15], making irrelevant comments [12] and drifting away from the topic [16]. Lack of self-monitoring and planning, caused by dysfunctions in the executive system, has been reported to correlate with an inability to provide the accurate amount of information and to put ideas together logically. Furthermore, attention deficit has been reported as a factor reflecting reduced ability to stay attentive when having a conversation and therefore getting sidetracked [15]. Communicative behaviour in people with severe TBI has also been reported to be more self-centred and communication partners have rated conversations with people with TBI to be more effortful [17].

Communication ability has been reported to break down at the discourse level for people with severe TBI and therefore discourse assessment has been recommended [18,19]. Discourse production can be either conversational or monologic and can comprise different genres e.g. narrative, procedural or conversational genres. Texts within the same genre have similar structures and linguistic organization [20]. To successfully manage any type of discourse task, a complex interaction between linguistic, pragmatic, cognitive and behavioural skills is needed. Failure to adequately integrate these skills underlies the difficulties people with severe brain injury have with discourse [19]. Different discourse tasks vary according to task demands and people with severe TBI vary in performance depending on the task they are given [21,22]. In conversational settings, people with severe head injury can fail to maintain the conversational topic, show poor turn-taking skills and may present situational inappropriateness [23]. Hartley and Jensen [24] found three different discourse profiles when investigating monologic narrative discourse in severe TBI. It appeared that participants who spent longer time in coma expressed an ‘impoverished discourse’. They presented an overall reduction in linguistic productivity (speaking time, total number of words and C-Units closely corresponding to an utterance, words/C-Unit, speech rate). Frequent pauses during the monologue and a reduced ability to express abstract relationships were also prominent in this subgroup. The other two profiles that the authors identified were ‘confused discourse’ and ‘inefficient discourse’. Participants belonging to the latter demonstrated a longer speaking time, higher number of words and C-Units, as well as a large proportion of mazes compared to the control participants. The participants with ‘confused discourse’ were distinguished from the other two profiles by displaying the highest amount of inaccurate content, the least amount of accurate content and the most difficulty with clarity. They also presented a very high number of mazes compared to the other participants and scored the lowest on the Western Aphasia Battery (WAB) [25].

Narratives (story retelling, story generation and personal event retelling), picture description and procedural description are different types of monologic discourses. These tasks have all been used in TBI and communication research, but narrative tasks are the most commonly researched [19]. Findings from studies analysing monologic tasks have consistently demonstrated impairments in linguistic productivity, efficiency, content accuracy and organization as well as story grammar and coherence [19]. These findings indicate that monologic discourses are sensitive to the communication deficits present in the population of severe TBI.

A procedural description consists of a goal that is accomplished through a sequence of actions or steps [26]. Procedural discourse is also a speech task closely related to real-life situations. In research, the given discourse task usually entails a description of a simple and commonly occurring day-to-day procedure e.g. How to buy groceries [21] or how to withdraw money from a bank account [27]. Sometimes it entails a more unusual description, although still simple, such as explaining a board/dice game [28]. Procedural texts have been identified as one of the key texts occurring at a workplace e.g. instructions to machinery or training manuals [29]. It is also a frequently occurring discourse in day-to-day life e.g. describing the way or giving instructions. Furthermore, this genre of discourse is taught as a part of the factual writing curriculum in schools today [26]. Thus, procedural discourse is a frequently occurring communication task and an important genre in both educational and employment settings.

The research exploring procedural discourse is sparse. In a study by Hartley and Jensen [21], the authors compared the performance on narrative tasks and a procedural task between 11 people with severe TBI and 21 healthy speakers. Compared to the control group on the procedural task, the patients with TBI were significantly less productive (shorter speaking time, fewer meaningful words, fewer C-Units, slower syllabic rate, more syllables in mazes), used significantly fewer cohesive ties (in total and fewer lexical ties) and were significantly impaired on information quality (fewer target content units, problems of reference). Further studies have demonstrated that when explaining a board game, people with severe brain injuries omit essential steps (essential steps are actions that need to be described for the procedure to be understood) in their description as well as add irrelevant content [28]. Snow et al., studied the perfomance of 26 people with severe TBI compared to a demographically distinct control group (26 people) and a demographically similar control group (26 people) on a procedural discourse task. Participants with severe TBI produced fewer essential steps compared to the demographically distinct control group. The authors also examined pragmatic features (quantity, quality, relation and manner) in the discourse. Compared to both control groups, people with TBI made significantly more errors with regard to topic maintenance, information redundancy and information insufficiency.

In previous research examining procedural discourse, the number of participants with TBI has been limited, ranging from 3 [22] to 26 [27]. The time between injury onset and time of testing has varied widely. For example, in some studies, time post injury can range from months to years. (e.g. [21,30,28]). However, Snow et al. [27] examined procedural discourse performance between 3 and 6 months post injury and this is the only study assessing participants with TBI within a distinct and narrow timeline. Snow et al.'s [27] is also the only research examining procedural discourse abilities with a larger participant sample at an early stage post injury, whilst most other studies have included very few participants during the sub-acute phase of recovery [21,28]. To date, there have been no follow-up studies examining procedural discourse as a measure of early communication recovery. Some follow-up research has been made in neighbouring discourses, such as narratives [18,31], conversational discourse [32], and narrative performance in people with aphasia [33]. However, the two follow-up studies by Snow et al. [31,32] were conducted more than two years post injury. Due to the lack of early follow-up studies, the nature of procedural discourse in early post injury stage in severe TBI is unknown. Consequently, our insight into communication and recovery in the very early phase after severe TBI is limited.

There are a number of ways to study performance on a monologic task. Common analyses are microlinguistic and macrostructural analyses [13]. At a microlinguistic level, within-sentence features are examined, and often involve analysing linguistic productivity. Linguistic productivity is generally measured in terms of total number of words, total number of utterances, words per utterance, total speaking time and words per minute or second [13]. The description of an utterance varies, but often closely corresponds to a T-Unit (minimal terminable unit; an independent clause plus any dependent clauses associated with it) [34]. Compared to healthy speakers, people with severe TBI have demonstrated reduced productivity in monologic discourses in terms of number of words, fewer T-Units, fewer words/T-Unit and fewer words/min (e.g. [35,21]).

The macrostructure of a discourse refers to aspects across the whole discourse. A discourse can be analysed for macrostructural features by looking at the coherence or the content of the text [13]. In procedural discourse specifically, this may mean examining propositions in the description as to whether they are essential, optional, irrelevant, ambiguous or added [28,27,36]. Analysing the macrostructure in procedural discourse in terms of different propositions is closely related to generic structure potential analysis (GSP). GSP is based on a text belonging to a certain genre, and depending on the genre, the text follows a predicted schematic structure [20]. The schematic structure of procedural monologues comprises a goal followed by a series of steps oriented to achieving the goal [26]. Previous research has shown that people with TBI produce fewer essential elements [28,27] as well as add more extra elements compared to controls [28].

In the current study, procedural descriptions are analysed in terms of linguistic productivity and macrostructural features. The aim of this study is to explore communication recovery in participants with severe TBI during the early stages post injury and compare it to the discourse behaviour of healthy speakers. The research questions are the following.

1. Will the people with TBI change in terms of linguistic productivity between 3 and 6 months post injury?
2. Will the discourse of people with TBI change in terms of macrostructural features between 3 and 6 months post injury?
3. Will the discourse behaviour in people with TBI differ from the discourse behaviour of the healthy speakers at 3 and 6 months post injury?

Method

The current study is a part of a longitudinal project examining communication recovery after severe TBI. In the longitudinal project, participants with severe TBI were assessed according to a standardized test protocol at 3, 6 and 12 months post injury. The TBI Bank protocol includes non-standardized speech tasks (monologic discourse tasks) and standardized tests or parts of standardized test batteries. In addition to this, the participants were recorded having a conversation with one other person. They were also assessed for the presence of dysarthria using the Frenchay Dysarthria Assessment (FDA) Test [37], presence of aphasia using the Western Aphasia Battery-Revised (WAB-R) [44] and both the participant and their significant other completed a self-evaluation form aimed at measuring their perception of their communicative ability using the La Trobe Communication Questionnaire (LCQ) [38]. Furthermore, participants also received a neuropsychological test protocol at each interval. The data for this paper were collected at three and six months post injury.

Participants

Table 1 shows an overview of the participants' demographic information, the lowest GCS that was reported, type and severity of aphasia and the Aphasia Quotient (AQ) from the WAB-R [44] at 3 months post injury. Table 1 also shows the presence of dysarthria at 3 months post injury, total scores on the FDA [37] and average hours of speech pathology intervention per week at 3 months post injury, as well as scores on the LCQ [38] for the participants with TBI and their significant others. Appendix C shows a full overview of the participants' AQ, aphasia type and severity at both time points. It also presents means and total scores from the FDA, as well as the presence of dysarthria at both time points.

The clinical group included 43 subjects, comprising 8 females and 35 males. Their age ranged from 17 to 67 years (mean = 36.2, SD = 13.7). Mean years of education was 14.1 (SD = 3.1, range = 8–20). All participants in the cohort group had sustained a severe TBI as defined by post-traumatic amnesia (PTA) longer than 24 hours and/or a Glasgow Coma Score (GCS) between 3 and 8 [39]. Length of PTA ranged from 3 to 122 days (mean = 46, SD = 29.4). The majority of the injuries were caused by involvement in motor vehicle accidents (MVAs) (28 people), followed by falls (8 people), assaults (5 people), gunshot (1), and train accident (1). Participants were recruited from the Sydney metropolitan area and from locations within 3 hours' travelling distance from Sydney. Participants were recruited when they were medically stable, generally meaning recruitment occurred at 2 months post injury. Participants from diverse cultural and linguistic backgrounds were included after consideration on an individual basis. Exclusion criteria for the longitudinal project were: history of previous neurological illness or injury or significant medical history (i.e. developmental delay), still in PTA, consent unable to be obtained from person with TBI or from significant other, more than 6 months since injury, patients not available for follow-up testing (i.e. a minimum of 2 data points). Further exclusion criteria for the current study were: unable to complete the protocol at 3 and 6 months post injury and not giving consent to recording of the assessment.

At the time of the first assessment 23 participants had aphasia. One had severe Broca's aphasia and the others mild anomic aphasia. 37 participants had dysarthria at the first assessment. The presence of dysarthria was based on a 9-point scale that accounted for ratings from A to D in the FDA Test [37]. A 7 on the 9-point scale equated to a B in the test and was defined as mild dysarthria. A score of 7 along the scale was used as a cut-off point to indicate the presence of dysarthria. At the second assessment 13 participants had aphasia and 26 participants had dysarthria (Appendix C). According to the FDA Perceptual Scale, a score of 9 reflects a perception of normal functions, whereas 7 corresponds with mild dysarthria, 5 with moderate dysarthria, 3 with severe dysarthria and 1 to no functions. Participants were diagnosed with dysarthria if they scored 7 or less on any of the 15 FDA items that included a speech component (Respiration b, Lips c-e, Palate b-c, Larynx-a-d, Tongue e-f, Intelligibility a-c). A total and mean speech score was also calculated for these 15 FDA items to provide an overall severity profile. The majority of participants with dysarthria had a mild form of this motor speech disorder that persisted at 6 months as indicated by the scores from the FDA (Table 1, Appendix C). The diagnosis of aphasia was based upon a WAB AQ cut-off score of 93.8. The WAB-R test manual stipulates that a score equal to or less than 93.8 indicates aphasic language performance. The diagnosis was made during the initial research assessment. If a participant was not diagnosed with aphasia and/or dysarthria at the first assessment he/she was not retested for these diagnoses at the time of the follow-up unless the participant or carer raised concerns regarding language or motor speech functioning.

At the first interval 37 people had or did receive speech therapy at an average of 1.9 hours per week (average range = 0.25–7, SD = 1.3 average hours/week). This information was derived from the participant's rehabilitation timetable and reports from rehabilitation staff.

The control group comprised a selected subset of the control participants (Wright and Capilouto) that were available from the shared online database AphasiaBank [40] The total number of control participants on AphasiaBank was 152, with ages ranging from 23 to 89 years (mean = 65, SD = 17.4). For the current study, a subgroup of controls were selected based on their age and years of education to match the TBI group. The selected control group included 37 American subjects, 24 females and 13 males. Their age ranged from 23 to 55 years (mean = 40.3, SD = 7.9). Mean years of education was 15.3 (SD = 1.8, range = 12–18). The control subjects had no history of stroke, head injury, other neurological conditions or cognitively deteriorating conditions. Their vision and hearing were adequate for testing based on clinical judgement or assessment, they had no depression at the time of the testing and were fluent in English.

Material

When the data for the current paper were collected, a standardized communication assessment protocol was used at each interval post injury. This protocol is available from AphasiaBank [40]. In addition to the protocol two other tests were carried out; the FDA Test [37] that assessed dysarthria and the LCQ [38], where people with TBI and a significant other evaluated their communication ability after the injury.

Total scores on the LCQ range from 30 to 120. Higher scores are consistent with the perception of frequent difficulties and lower scores with less frequent difficulties.

The assessment protocol consisted of four different discourse categories and six linguistic tests: Aphasia Bank Repetition Test [41], Verb Naming Test (from the Northwestern Assessment of Verbs and Sentences) [42], Boston Naming Test, Short Form [43], Western Aphasia Battery-Revised (part AQ only) [44] and verbal fluency (F, A, S). The discourse categories included two free monologic speech tasks, three picture descriptions, one story narrative and one procedural description task.

The current paper is concerned only with the procedural discourse task. In the original protocol, subjects were asked to describe how they would make a peanut butter and jelly sandwich. Since the protocol was developed for international use, another type of sandwich description that better suits the local context is allowed. Hence, in the current study the procedural discourse task instead described how to make a cheese and Vegemite sandwich. The control group data included the procedural description according to the original protocol.

Procedure

All the discourse tasks were audio and video recorded. Participants still receiving inpatient care were assessed at the rehabilitation unit. Participants receiving outpatient care were assessed either at a rehabilitation centre or at home. Completion of the protocol and the additional tasks (conversation, dysarthria assessment and self-evaluation form) took approximately 4.5 hours (not including the neuropsychological component). Due to the extensive assessment most appointments were completed over several sessions.

The instructions for the procedural discourse task were: ‘Let’s move on to something a little different. Tell me how you would make a cheese and Vegemite Sandwich’. If the participant did not respond within 10 seconds or if the participant gave a very incomplete description the investigator could give a verbal prompt (i.e. ‘is there anything else you can tell me?’). If the participant still didn’t respond to the instructions visual prompts could be given (pictures of the ingredients). None of the participants with TBI needed picture prompts. 6 participants were given verbal prompts after giving very short descriptions of the sandwich procedure. On one occasion the investigator accidently gave the first half of the instruction for a peanut butter and jelly sandwich. The investigator then revised the instruction and gave the correct instruction (cheese and Vegemite). The participant mentions both versions of the sandwich in his description. Since the correct instructions were given before he initiated the description the discourse was analysed normally.

Discourse samples were transcribed orthographically and coded according to coded in CHAT (Appendix A). The transcriptions were segmented into utterances, which closely corresponded to a T-Unit (an independent clause plus any dependent clauses associated with it) [34]. To segment the speech samples into utterances the following indicators were considered with primary weight on the first and second indicators: (1) Syntax – a well-formed sentence was considered to be an utterance, (2) Intonation – falling or rising (in the case of a question) intonation indicated the end of an utterance, (3) Pauses – unless they occurred in what appeared to be an otherwise well-formed sentence, and (4) Semantics – the speaker changed the topic. The above indicators are the guidelines given in the CHAT manual (Appendix A). The first author who transcribed the procedural discourse tasks and the experienced speech and language pathologist (SLP) who conducted reliability testing were both blinded as to whether the sample was recorded at three or six months post injury and to any participant background information.

Eighteen (20%) transcriptions (9 from each post injury interval) were randomly selected and checked for transcription and CHAT coding accuracy. The transcriptions were transcribed again by the first author, E.S, (intra-rater reliability) and inspected by an experienced SLP (inter-rater reliability). Due to audio technical problems only 17 (19.77%) transcriptions were inspected by the experienced SLP for transcription accuracy. The same 18 transcriptions as well as 8 samples from the control group (a total of 26 transcriptions, 21% of the whole group of participants) were reanalysed for macrostructural elements by E. S, and analysed by the experienced SLP mentioned above. Reliability checks were conducted at least two weeks after the transcriptions and macrostructural analyses were conducted.

The control group had completed the same protocol, the only difference being the instruction for the procedural task (‘Tell me how you would make a peanut butter and jelly sandwich’). The control group’s audio/video recordings and transcriptions were available from AphasiaBank [40]. The transcriptions were already coded according to CHAT and segmented into utterances following the guidelines provided in the CHAT manual. Their transcriptions were checked for accuracy at the time that they were downloaded from AphasiaBank.

Productivity

Productivity measures included the total number of meaningful words (repeated and revised words as well as fillers were not included), total number of utterances, speaking time, speech rate and words per utterance. Speaking time was measured in seconds. It was measured from the second that the participant first started to speak after being given instructions, to the second they uttered their final word. Hence, introductory comments such as ‘A cheese and Vegemite sandwich’ or questions such as ‘Should I tell you how to make a cheese and Vegemite sandwich?’ were included, as well as final comments such as ‘that’s it’. Speech rate was derived by dividing the total number of words in a sample with the length of the utterance (words/second). Values for the total number of words, total number of utterances and words/ utterance were analysed by CLAN. All productivity measures were conducted on transcripts from both the TBI and control groups.

Macrostructure

The macrostructure of the procedural discourse was measured in terms of essential steps, optional steps and low content elements. The macrostructural elements were analysed according to a checklist (Appendix B).

Based on 80% of the content control participants included in their procedural description and the essential steps suggested by Ulatowska et al. [36], six essential steps were identified. Since the essential steps were derived from the control group that described a different sandwich, the steps were adjusted to account for responses from both the control group and the people with TBI. The six essential steps were (1) Get the bread, (2) Get the peanut butter/Vegemite, (3) Get the jelly/cheese, (4) Put the peanut butter/Vegemite on the bread, (5) Put the jelly/ cheese on the bread, (6) Put it together/Fold together/Put on top.

A list of optional steps was developed to simplify the macrostructural analysis. Based on Snow et al. [27], steps that less than 80% of the controls mentioned were identified as optional. These steps still had to be in accordance with Ulatowska et al.’s [36] definition of an optional step. Namely, it had to clarify, add or give more detail beyond the essential steps. An optional step was considered to be at the same hierarchical level as essential steps because they produced new actions beyond the essential elements. In contrast, sub steps comprised finer detail for already existing steps. To the list of optional steps derived from the control group’s responses, four steps were added. Three of the steps were options being very likely to appear in the Vegemite sandwich (grate/slice the cheese, get butter, butter the bread). The fourth added step, not actually fitting into the definition of an optional step, was a ‘Goal/target step’ e.g. ‘and that is a peanut butter and jelly sandwich’. This step was mentioned by a number of controls and people with TBI and appeared to be a natural final element; therefore it was included as an optional step.

Low content elements could be repeated information (that did not bring a new action to the procedure) e.g. ‘undo the lid to the Vegemite’ and later ‘take the lid off the Vegemite’, irrelevant information e.g. ‘if I was making the sandwich for X’ or tangential/ambiguous steps e.g. questions in the middle of the description or interrupted steps.

In each transcript, utterances or parts of utterances were marked as to which of the three macrostructural categories they belonged. In the occurrence of low content elements, it was also specified if it was a matter of repetition, irrelevance or tangentially/ambiguous responses. The essential steps could be either stated or inferred by the speaker. The utterance ‘Get the Vegemite’ is stating step 2. An utterance such as ‘I spread the Vegemite on the bread’ is stating step 4 but also inferring that step 2 has already been carried out. The same optional step could occur multiple times, as long as it involved a new action and was not a repeated step. For example, ‘undo lid/take lid off jar’ for the butter and then later saying ‘undo lid/take lid off jar’ for the Vegemite is the same optional step used twice, but referring to different actions. Following coding of the steps, the total number of essential steps, optional steps and low content elements were summarized.

Ethical considerations

The longitudinal communication recovery project received ethics approval from the University of Sydney and the participating health sites.

Statistical analyses

Tests of normal distribution showed skewed distribution in years of education, the total number of essential steps and the total number of low content elements.

For within-group measures paired sample t-tests were used to compare the linguistic productivity of the TBI group between 3 and 6 months post injury. Wilcoxon signed rank tests were used to analyse changes in the number of essential steps and number of low content elements between 3 and 6 months post injury. The total number of optional steps was normally distributed and was analysed with a paired sampled *t*-test. Finally, a Wilcoxon signed ranks test was used to analyse differences in change over time between optional steps and low content elements. Due to multiple comparisons a partial Bonferroni adjustment was set for each series of within-group measures (9 tests in 1 series). The alpha was set to 0.0056 for all within-group measures. A partial adjustment was used to balance the control for type I errors with the increased risk of type II errors [45].

For between-group measures independent *t*-tests were used to analyse the differences in productivity between the control group and the TBI group at 3 and 6 months post injury. Mann–Whitney *U*-tests were used to analyse the number of essential steps and the number of low content elements. The number of optional steps were analysed with independent *t*-tests. Due to multiple comparisons a partial Bonferroni adjustment was set for each series of between-group measures (8 tests in 2 different series). The alpha was set to 0.0063 for all between-group measures. A partial adjustment was used to balance the control for type I errors with the increased risk of type II errors [45].

Results

Transcription, CHAT coding and segmentation accuracy reached 92.96% in intra-rater reliability, and 92.72% in inter-rater reliability. Macrostructural ratings reached 91.21% in intra-rater reliability, and 81.21% in inter-rater reliability. All reliability measures reached the minimum acceptable level (80%).

Descriptive statistics for both productivity and macrostructural variables are presented in Table 2. Mean and SD are presented for normally distributed variables. Median, range and inter-quartile range are presented for the variables with skewed distribution. The control group and the TBI group did not differ in age ($t(78) = 1.68$, $p = 0.097$) or years of education ($z = -1.78$, $p = 0.076$) (Table 3).

The first research question asked whether people with TBI changed in terms of linguistic productivity between 3 and 6 months post injury. Participants with TBI produced fewer words, and fewer utterances at 6 months post injury than they did at 3 months post injury. However, these changes were not significant. At 6 months post injury the TBI group spoke for a shorter time than they did at 3 months post injury. This change was also not significant. The people with TBI produced fewer words per utterance at the second interval compared to the first, and had little change in their speech rate (words/second) between the two time points. Neither speech rate nor number of words per utterance differed significantly between 3 and 6 months post injury. The people with TBI became less varied in the number of words and utterances at 6 months post injury compared to at 3 months post injury. At the second interval the TBI group showed as much variation in the number of words as the controls did, and they varied less than controls in the number of utterances. Furthermore, the speaking time was more varied in the TBI group at both time points compared to the speaking time in the control group.

The second research question addressed whether there was a change in macrostructural features of the sandwich retell task from 3 to 6 months post injury. Whilst the number of essential steps did not change significantly between the two time points, the range in the number of essential steps decreased at 6 months (Table 2). Similarly, the number of low content elements did not change significantly between the two time points. However, the range in the number of low content elements decreased at 6 months post injury compared to 3 months post injury. The number of optional steps increased from 3 to 6 months post injury, but this increase was not significant (Table 2).

Difference scores were also calculated to examine the change in the number of optional and low content elements between 3 and 6 months post injury and these difference scores were then compared. In comparing the change in the number of optional steps from the first to the second interval, to the change in the number of low content elements from the first the second interval, significant differences emerged. Difference scores were derived for both the number of optional steps and low content elements between the two time points. Difference scores were dervied from the number of optional steps at the 6 month time point subtracted from the number of optional steps at the 3 month time point. Furthermore, an additional difference score was derived by calculating the number of low content elements at the 6 month time point minus the number of low content elements at 3 months post injury. The difference in the amount of change between the optional steps and the low content elements was significant ($z = 1.398$, $p < 0.001$). The change in the number of optional steps between 3 ($M = 3.6$, $s = 2.5$) and 6 months ($M = 4.4$, $s = 2.4$) post injury was significantly greater than the change in the number of low content elements between 3 ($M = 2.3$, $s = 2.6$) and 6 months ($M = 1.7$, $s = 2$) post injury. Figure 1 illustrates the change in optional steps from the first to the second interval, compared to the change in low content elements from the first to the second interval. Nine people had a smaller change in the number of optional steps compared to their change in the number of low content elements between the two time points (change in optional steps between 3 and 6 months < change in low content elements between 3 and 6 months post injury). Meanwhile, 29 people showed a greater change in the number of optional steps between the two intervals compared to how they changed in the number of low content elements between the two intervals (change in optional steps between 3 and 6 months > change in low content elements between 3 and 6 months post injury). Five people changed as much/as little in the number of optional steps as the number of low content elements between the two time points (change in optional steps between 3 and 6 months = change in low content elements between 3 and 6 months post injury). The distribution of the amount of change in optional and low content elements between the two intervals is illustrated in Figure 2.

The third research question examined whether differences existed between TBI and control participants in the sandwich retell task. At 3 months post injury people with TBI produced fewer words and fewer utterances compared to the controls. However, the differences were not significant. At 6 months post injury the TBI group produced even fewer words and utterances compared to the controls, but these differences did not reach significance. In terms of speaking time, the people with TBI spoke for a shorter time than the controls at both time points. However, neither at 3 months or 6 months post injury did the speaking time reach significant difference between the groups. The number of words per utterance was lower in the TBI group at both 3 and 6 months post injury compared to the controls, but these differences did not reach significance. At both the first and second interval post injury the TBI group had a significantly slower speech rate (words/second) compared to the control participants (Table 3).

There was a significant difference in the number of essential steps between the control group and the people with TBI at both 3 months and 6 months after the injury. As can be seen in Table 2, the median did not differ between the controls and the people with TBI at either time point. However, all the healthy speakers mentioned all essential steps, whereas people with TBI mentioned 0–6 essential elements at 3 months post injury, which increased to 3–6 essential elements at 6 months post injury. The number of low content elements was significantly higher in the TBI group at 3 months post injury. Although, at 6 months post injury there was no longer a significant difference between the controls and the people with TBI in the number of low content elements produced. Finally, the number of optional steps differed between the control group and the TBI group. The control participants produced a significantly larger amount of optional steps than the people with TBI did at both 3 and 6 months post injury.

Discussion

This is the first study that has examined linguistic behaviour in procedural discourse at two distinct time points in the very early stages of recovery after a severe TBI. No significant changes were seen in the TBI group in terms of linguistic productivity or macrostructural elements from 3 to 6 months post injury. However, the change in number of optional steps from 3 to 6 months post injury was significantly larger compared to the change in number of low content elements between the two intervals. This indicated a pattern, that the TBI group increased the production of optional steps during the first months of recovery. The control subjects had a significantly faster speech rate and mentioned significantly more essential and optional steps compared to the TBI group at both intervals post injury. Furthermore, only at 3 months post injury did the participants with TBI produce a significantly higher number of low content elements than the controls.

Even though no significant changes were seen between the two time points in terms of linguistic productivity, the people with TBI appeared to show less variability in the number of words and utterances at 6 months post injury compared to 3 months post injury. The move towards a reduced variability may be a subtle sign of improvement in early recovery.

In the current study, the clinical group showed a high incidence of aphasia and dysarthria at both 3 and 6 months post injury. The number of participants with TBI diagnosed with dysarthria and aphasia decreased at the follow-up and for the majority of the participants the dysarthria and aphasia were mild (Appendix C). However, the speech disorders are likely to have had an effect on the results as measures in the current study essentially examine verbal output, and is discussed below in relation to the findings.

No change was observed in speech rate in the TBI group from 3 to 6 months post injury. However, the speech disorders may have had an effect on findings, given that the measures were reporting verbal output. A majority of the participants with TBI had dysarthria at 3 months post injury. And even though this decreased at 6 months post injury, a little more half of the participants with TBI still had dysarthria at the second assessment (Appendix C). This is consistent with previous research that has shown that dysarthria is a persistent communication disorder in the TBI population [5,6]. Persistent dysarthria is likely to be the underlying cause as to why there was no significant change in speech rate between the two time points. It is also a likely explanation to why the TBI group differed from the control group in speech rate at both 3 and 6 months post injury. In the current study it appears that dysarthria mainly had an effect on speech rate as that was the only productivity measure that showed significant difference between the TBI group and the controls at both time points. Perhaps this was due to the mild forms of dysarthria observed in the cohort group. Hartley and Jensen [21] also examined performance on a procedural discourse task and reported reduced speech rate among the people with severe TBI compared to control participants. Similar findings have been reported in previous monologic discourse research [46,35,30]. Hartley and Jensen [21] reported that the presence of dysarthria was a likely contributing factor for the reduced speech rate in their TBI group. They also hypothesized that reduced psychomotor speed and a general slowness of thinking and movement were other factors that could contribute to the slower speech rate. Marini et al. [30] suggested that frequent interruptions in the flow of thoughts could be the main cause of reduced speech rate in their severe TBI group. However, no information regarding the presence of dysarthria was reported for the participants with TBI in their study. Hence, it is possible that some of the people with severe TBI in Marini et al. [30] did have dysarthria that may have contributed to the reduced speech rate.

Since the people with TBI demonstrated normal amounts of verbal output at 3 months post injury (except in speech rate) a change over time in the TBI group was not to be expected. The nature of the procedural description task may have affected the amount of verbal output being elicited. A description of how to make a sandwich is a very structured task following quite a distinct sequence [26] and the overall level of constraint is low [47]. The structured nature of this discourse task may contribute to a more definite amount of linguistic productivity and therefore the TBI group performed in a similar manner to control group in relation to the amount of verbal output. This is in contrast to Hartley and Jensen's [21] analysis of procedural discourse whereby the people with TBI spoke for a significantly shorter time, produced significantly fewer words and C-Units (closely corresponding to an utterance) compared to the control participants. The procedural discourse task in Hartley and Jensen [21] comprised a description of how to buy groceries which has a different number of essential macrostructural elements. Hence, it is possible that the difference in the core details between that description task and the current discourse task contributed to the contrasting results.

In this study the number of meaningful words was used as one of the productivity measures, i.e. repetitions, revisions and fillers (mazes) were excluded from the word count in order to generate a more reliable word count. Previous studies have reported mixed results regarding maze behaviour. Some studies have reported significantly more mazes in the TBI group compared to controls [21,24]. Other studies have reported no significant differences either between the TBI group and demographically similar controls, or differences between the TBI group and demographically distinct controls (higher education) [27]. Thus, it would be of interest to further analyse discourse productivity in relation to maze behaviour and whether changes occur during recovery.

Between 3 and 6 months post injury the individual scores on optional steps and low content elements did not change sufficiently to be statistically significant. With the number of low content elements, the relatively low mean at 3 months post injury may have left little room for any significant decrease to appear during the 12 weeks of recovery. However, a significant difference was found between the *change* in optional steps between the two time points compared to the *change* in low content elements between the two time points. The TBI group changed more in the number of optional steps they produced between 3 and 6 months post injury, than they changed in the number of low content elements they produced between 3 and 6 months post injury. This indicated a subtle pattern whereby people with TBI increased the number of optional steps as they recovered. It also implies that after only a few months of recovery the people with TBI appear to spend more time on optional, but still relevant, information in their procedural descriptions. This pattern indicates the onset of an improvement in the TBI group, as the discourse behaviour began to approximate that of the healthy speakers. In relation to the results described above, it is also worth noting that the TBI group no longer differed significantly from the controls in terms of low content elements at 6 months post injury, as well as the fact that the speaking time did not change between the two time points. Taken together, the pattern that the TBI group produced more optional steps, combined with a decrease in the number of low content elements, and no change in speaking time, indicates that they spent more time on relevant information, and replaced irrelevant content with relevant information as they recovered. This change may reflect improvements in mental organization and planning as the people with TBI became better at including more detailed information whilst keeping it relevant. It may also reflect increased inhibition abilities as irrelevant information was omitted to a greater extent.

In spite of this improvement, between-group comparisons showed that the healthy speakers generated significantly more optional steps at both time points post injury. Snow et al. [27] also examined the use of optional information in a procedural discourse task and the mean percentage of optional steps was higher in both the demographically distinct (higher education) and similar control groups compared to the participants with TBI. Rather than comparing the percentage of optional steps between the TBI group and the 2 control groups Snow et al. [27] combined the proportions of optional and essential information into an 'on-target output'. The TBI group generated significantly less 'on-target output' compared to the demographically distinct control group. Since the optional steps are sub steps or more detailed steps in relation to the essential steps, generating an optional step is highly dependent on planning and organizational skills as well as memory. Thus, as difficulties were evident with the essential information, it is not surprising that people with TBI also had difficulty with the optional elements.

In the current study people with TBI produced significantly more low content elements compared to the controls at 3 months post injury. Low content elements included repeated, tangential (questions or ambiguous comments) and irrelevant information. Hence, a higher amount of low content elements reflects cognitive impairments. Irrelevant responses may represent difficulty with inhibition. Repetitions and requests for clarification may be related to poor memory and planning difficulties. Tangential information, such as not providing enough information in an utterance for it to be understood, demonstrates pragmatic difficulties and limitations in taking the listener perspective. As the participants with TBI no longer mention significantly more low content elements after 12 weeks of recovery, this could indicate improved cognitive functioning. The difference seen in low content information between the TBI group at 3 months post injury and the controls is consistent with previous findings. McDonald and Pearce [28] found that people with TBI produced a significantly higher proportion of extra information compared to controls during their procedural dice game task. They also reported that the features of the TBI discourse in their study, i.e. fewer essential steps and more irrelevant content, resembled conversational styles arising from dysfunctions in the executive system. This lends support to the view that impaired planning and organization is contributing to the discourse behaviour in the current study. Snow et al. [27] also reported a higher mean percentage of redundant output (repeated or irrelevant information) in TBI discourse compared to controls. However, these differences were not compared statistically.

The TBI group did not change in their production of essential steps from 3 to 6 months post injury, although, at 6 months the variability in number of covered essential steps was reduced in the TBI group. This may be an indication of improvement for some of the participants with TBI, as none of them omitted more than half of the steps after 12 weeks of recovery. However, this must be considered with caution as most of the participants with TBI covered more than half of the essential steps at both time points. Snow et al. [27] also analysed the production of essential steps in a procedural discourse in people with severe

TBI concluding that the people with TBI were clearly able to select and provide information in procedural steps. The results from the current study, where a large amount of essential steps were covered at both 3 and 6 months post injury, support Snow et al.'s conclusion.

Snow et al. [27] also reported that even if the people with TBI in their study were able to select and provide procedural information in steps, they made a number of pragmatic errors and differed significantly from healthy speakers in discourse performance. The same could be said about the TBI group in the current study. They presented the procedural information in steps and covered a large amount of essential steps, but they also included a significantly higher number of low content elements. Furthermore, the people with TBI covered significantly fewer essential steps at both 3 and 6 months post injury compared to the control participants, all of who covered each essential step. This shows the great difficulties that people with TBI experience even in a highly structured and simple communication task. After 12 weeks of recovery the TBI group still omitted basic procedural steps that were essential for the task description. Yet again, impaired memory, planning and organizational abilities could account for the poorer performance in the TBI group. Many of their discourse samples appeared disorganized as steps were commonly revised and the procedural descriptions were restarted, a behaviour likely caused by poor planning and organization. The essential bits of information may then have been omitted due to the disorganized verbal output as well as problems with memory. Correlations between narrative discourse performance and working memory in moderate to severe TBI have been reported [48]. Poor working memory is likely to also affect procedural discourse performance. The findings from this study in terms of differences in essential steps between controls and participants with TBI are similar to those in Snow et al. [27]. However, they found that it was only between the TBI group and a demographically distinct control group that significant differences in essential steps occurred. Hartley and Jensen [21] examined the number of target content units in procedural discourse. A target content unit was defined as a proposition that at least 80% of the controls used, which makes it almost equivalent to an essential step. In their study they found the same difference between the controls and the TBI group as in the current study, i.e. the participants with TBI generated significantly fewer target content units/ essential steps compared to the controls. McDonald and Pearce [28] also reported people with TBI to produce significantly fewer essential steps. Furthermore, the TBI group in their study showed a larger amount of variability in the number of essential steps that they covered compared to the controls, consistent with the findings in this study.

In the current study, macrostructural measures (essential, optional and low content information) were used to examine the quality and quantity of verbal output. The inclusion of more essential and optional steps were discourse behaviours that were associated with better performance on the task as it meant the provision of more relevant information. Expressing low content elements on the other hand, was associated with a deviant discourse behaviour. The more low content elements that were included the worse the performance. Differences between the TBI group and the healthy speakers were observed in these macrostructural discourse behaviours, as well as speaking rate, as has been discussed above. However, it is of importance to address the fact that a large number of participants with TBI at both 3 and 6 months post injury had aphasia and dysarthria. The effect of dysarthria on speech rate results has been discussed above. Regarding the differences observed in number of essential and optional steps between the healthy speakers and the TBI group, it is possible that the TBI group expressed fewer essential and optional steps as a primary consequence of aphasic difficulties (e.g. word retrieval), rather than difficulties with discourse organization. Hence, the indication of improvement at 6 months post injury discussed above may be the result of recovery from aphasia and dysarthria (Appendix C). In contrast to this, the TBI group did express significantly more low content elements at 3 months post injury compared to the healthy speakers. This shows that even though aphasic difficulties compromise the ability of participants with TBI to express as much relevant information as the controls, the TBI group deviate in the type of content they produce. For future studies it would be of interest to examine productivity and macrostructure performance in relation to participants with TBI with and without aphasia to gain further understanding of primarily aphasic difficulties and/or impoverished discourse planning and structure.

In the current study, people with TBI demonstrated impoverished quality of procedural discourse. The results from analysing both macrostructure and linguistic productivity confirm the importance of analysing TBI discourse on more than one linguistic level, e.g. microlinguistically and macrostructurally, which has been emphasized in previous reports [18,49,50,51]. The findings have provided an indication of how debilitating the communication difficulties might be for people with severe TBI in the early stages of recovery. It is not hard to imagine the difficulties that this population will have during their conversations when performance in a structured and simple discourse task is significantly impoverished, and how this would have many negative impacts on quality of life and close relationships. The difficulties seen still at 6 months post injury may also indicate a delay in return to employment. In many cases persistent communication difficulties may also impact upon future employment completely.

However, indications of improvements in optional steps and low content elements were observed between 3 and 6 months post injury and further research at a later stage in recovery is needed. Discourse analyses at, for example. 12 months post injury would provide insight into whether the people with TBI improve further in discourse behaviour. Some of the participants received speech and language therapy during these first months of recovery. Treatment may also have contributed to the indicated improvements. A number of other discourse tasks were assessed at the two time points, all more complex than the procedural description. Hence, further research into those genres will provide important knowledge about the communicative recovery in early post TBI.

The great difficulties with the procedural description, still observable at 6 months post injury, offer an explanation to why there was no significant change in the individual scores on macrostructural elements between the two time points. 12 weeks between assessments may be too little time to detect significant changes in macrostructural behaviour, which lends further support to the idea of a follow-up at a later stage.

The findings in the current study suggest the importance of including procedural description tasks in clinical communication assessments. Not only does the performance on the procedural discourse task give some indication of the overall communication deficits. It is also a valuable assessment tool especially for those who are looking to return to work after a TBI. As procedural texts and discourses are key workplace texts and are also common in everyday life [29], it may be appropriate to train procedural description performance as a part of communication intervention.

There are a number of limitations to this study and therefore the findings should be viewed with caution. The number of participants with severe TBI was higher in this study than within any previous research examining communication in severe TBI. However, the sample size can still be considered limited. The procedural description was the very last discourse task in the TBI protocol, as it was considered to be the easiest of the different discourse tasks. However, fatigue may have had an effect on the results. Finally, the controls and the people with TBI were assigned to describe very similar tasks, the only thing differing between the tasks being the type of sandwich they were describing. Both types of sandwiches are deeply embedded in the participant's culture and should elicit very similar linguistic output. However, the fact that the two groups essentially described different details of the procedure may have affected the results.

In conclusion, the procedural discourse task was a useful tool for examining recovery of cognitive communication skills following severe TBI. Whilst most participants were able to recount the essential elements of how to make a cheese and Vegemite sandwich, this very structured controlled task presented challenges to the executive functioning of participants with TBI and cognitive skills which were reflected in production of repeated information, tangential responses, poor planning of responses and reduced communicative efficiency. This task is therefore recommended as one way of measuring communicative recovery during the sub-acute phase. It is also recommended, however, that this task be completed as part of a battery of discourse tasks, such as those presented in the TBI Bank protocol, in addition to an evaluation of the person's conversational skills with their everyday communication partners [52]. Further research is needed to evaluate the sensitivity of different discourse genres to detect recovery longitudinally, and also to examine the relationship between discourse outcomes, neuropsychological functioning and psychosocial recovery over time. This information will assist clinicians to identify evidence-based assessments, which are relevant to the person's everyday life outcomes, and can therefore inform contextually relevant treatment decisions.

Appendix A

CHAT coding

? question

! exclamation

@n neologism

Exclamations common ones: ah, aw, haha, ow, oy, sh, ugh, uhoh

Interjections common ones: mhm, uhuh, hm, uhhuh

Fillers common ones: &um, &uh

xxx unintelligible speech, not treated as a word

xxx@a unintelligible speech, treated as a word

&text phonological fragment (&sh &w we came home)

&=text simple local event and gestures (&=laughs, &=sighs, &=ges:fishing)

() shortenings e.g. runnin(g) for running, (be)cause

[/] the word preceding this code is repeated (the [/] the bread)

<text>[/] the words preceding this code is repeated (<the bread> [/] the bread)

[//] the word preceding this code is revised (I put the butter in [//] on the bread)

<text>[//] the words preceding this code is revised (I <put the jelly> [//] put the butter on the bread)

Utterance segmentation

Consider the following indicators with primary weight on syntax and intonation:

1. Syntax – unless there are strong prosodic counter-indications, a well-formed sentence is considered to be an utterance. However, and utterance may not necessarily be grammatically correct to be considered an utterance.

2. Intonation – falling intonation (or rising intonation in the case of a question) suggests the end of an utterance.

3. Pauses – may not be a reliable guide to utterance boundaries. When pauses occur in what appears to be otherwise well-formed utterances, disregard them.

4. Semantics – the speaker changes the topic.

Appendix B

Macrostructure analyses checklist

Essential steps

1. Get bread Y/N

2. Get peanut butter/Vegemite Y/N

3. Get jelly/cheese Y/N

4. Put on the peanut butter/Vegemite Y/N

5. Put on the jelly/cheese Y/N

6. Put together/put bread on top Y/N

Total number of essential steps:___

Optional steps

1. Two slices of bread ____
2. Take bread out of bread bag ____
3. Take a knife ____
4. Lay slices out/on a plate/table ____
5. Unscrew lid/open jar ____
6. Take ingredient out of jar ____
7. Cut/slice the bread ____
8. Eat the bread ____
9. Goal step e.g. 'that is a Vegemite Sandwich' ____
10. Get butter ____
11. Butter the bread ____
12. Buy bread/ingredients ____
13. Go to fridge/cupboard/bread container ____
14. Put ingredients on counter ____
15. Assemble items ____
16. Open bread bag/untwist bag/undo tag ____
17. Toast the bread/grill sandwich ____
18. Bring out a plate ____
19. Slice/grate the cheese ____
20. Wipe/clean/put down the knife/spoon ____
21. Lick off the knife ____
22. Close jar/put lids back on/close bread bag ____
23. Cut crust off ____
24. Serve the sandwich ____
25. Other optional steps (not classified as irrelevant): ____

Total number of optional steps:____

Low content elements

1. Repeated___

2. Irrelevant___

3. Tangential/ambiguous___

Total number of low content elements:___

Appendix C

Table presenting the participants' Aphasia Quotent (AQ) on the Western Aphasia Battery (WAB), severity and type of aphasia at 3 and 6 months post injury. The table also presents means and total scores on the Frenhcay Dysarthria Assessment (FDA) at 3 and 6 months post injury and presence of dysarthria at 3 and 6 months post injury.

Subject	[b]WAB, AQ 3 months	[c,d]Aphasia severity 3 months	Aphasia type 3 months	WAB, AQ 6 months	Aphasia severity 6 months	Aphasia type 6 months	Dysarthria 3 months	FDA total speech score 3 months	FDA total mean score 3 months	Dysarthria 6 months	FDA total speech score 6 months	FD tot me scor mon
1	88.5	Mild	Anomic	90.8	Mild	Anomic	Y	92	6.69	Y	90	6.7
2	99.2	N		N			Y	118	8.12	Y	122	8.2
3	97.6	N		N			N	131	8.85	N		
4	91.8	Mild	Anomic	97.6	N		Y	121	8.15	Y	109	7.5
5	95.3	N		N			Y	103	7.19	Y	107	7.4
6	97.9	N		N			Y	126	8.62	N	131	8.8
7	91.5	Mild	Anomic	94.6	N		Y	108	7.50	Y	113	7.7
8	92.4	Mild	Anomic	89.6	Mild	Anomic	Y	120	8.12	Y	128	8.5
9	95.9	N		N			Y	124	7.65	Y	127	8.0
10	80.3	Mild	Anomic	85.7	Mild	Anomic	Y	87	6.35	Y	90	6.3
11	95.3	N		N			N	131	8.77	N		
12	91.3	Mild	Anomic	91.6	Mild	Anomic	Y	96	6.88	Y	100	7.2
13	92.6	Mild	Anomic	96.2	N		N	132	8.85	N		
14	100	N		N			Y	127	8.23	Y	129	8.6
15	93.6	Mild	Anomic	92.5	Mild	Anomic	Y	127	8.65	N	134	8.8
16	84	Mild	Anomic	89.4	Mild	Anomic	Y	124	8.54	Y	127	8.6
17	90.9	Mild	Anomic	90.9	Mild	Anomic	Y	103	7.54	Y	124	8.3
18	100	N		N			N	128	8.73	N		
19	93.4	Mild	Anomic	93.6	Mild	Anomic	Y	124	8.50	N	129	8.6
20	N/A	N/A		98.8	N		Y	117	8.12	Y	117	8.0
21	84.5	Mild	Anomic	94	N		Y	123	8.38	N/A		
22	N/A	N/A		N/A			Y	121	8.46	N/A		

Subject	bWAB, AQ 3 months	c,dAphasia severity 3 months	Aphasia type 3 months	WAB, AQ 6 months	Aphasia severity 6 months	Aphasia type 6 months	Dysarthria 3 months	FDA total speech score 3 months	FDA total mean score 3 months	Dysarthria 6 months	FDA total speech score 6 months	FD tot me scor mon
23	92.4	Mild	Anomic	96	N		Y	95	7.15	Y	118	8.3
24	93.2	Mild	Anomic	95.8	N		Y	126	8.62	Y	114	8.1
25	86.3	Mild	Anomic	94.4	N		Y	127	8.38	N	129	8.5
26	91	Mild	Anomic	96.4	N		Y	123	8.23	N	133	8.8
27	92.5	Mild	Anomic	93.6	Mild	Anomic	N	130	8.77	N		
28	97.1	N		N			Y	127	8.62	N	132	8.8
29	88.6	Mild	Anomic	93.1	Mild	Anomic	Y	108	7.65	Y	122	8.2
30	97	N		N			Y	122	8.19	Y	119	8.1
31	92.8	Mild	Anomic	N/A			Y	120	7.85	Y	115	8.0
32	50	Severe	Broca	77.3	??	??	Y	112	8.00	N	123	8.4
33	96.4	N		N			Y	127	8.62	Y	127	8.5
34	92.1	Mild	Anomic	89.4	Mild	Anomic	Y	69	5.69	Y	92	7.1
35	87.1	Mild	Anomic	89.4	Mild	Anomic	Y	120	7.88	Y	121	8.1
36	95	N		N			Y	129	8.54	N	130	8.7
37	94.8	N		97.4	N		Y	102	7.15	Y	119	8.0
38	92	Mild	Anomic	N/A	N/A		Y	122	8.50	Y	125	8.4
39	95	N		N			N	135	9.00	N		
40	96.6	N		N			Y	133	8.62	N	133	8.8
41	96.2	N		N			Y	124	8.42	Y	124	8.3
42	95.4	N		N			Y	122	8.19	Y	124	8.3
43	88.5	N		N			Y	124	8.42	Y	129	8.6

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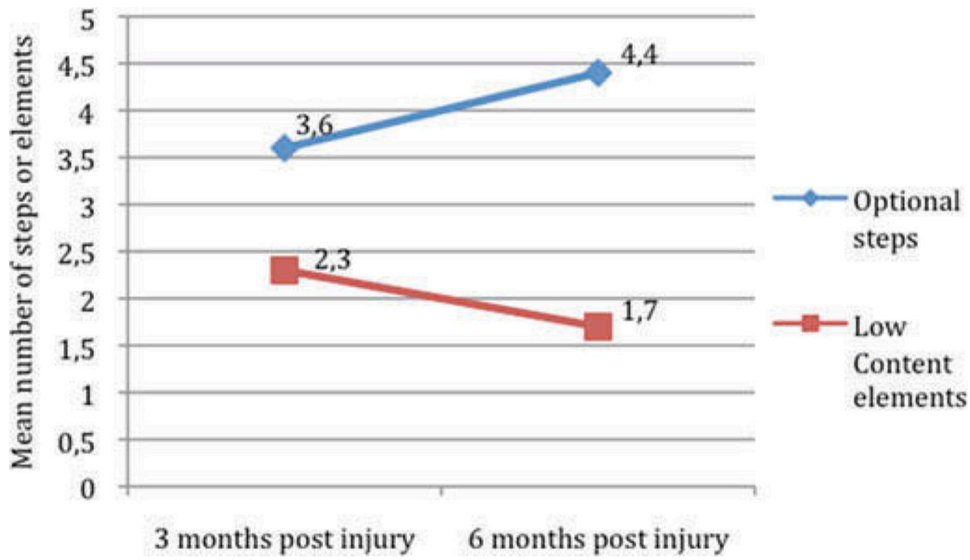

Figure 1.

Differences in the amount of change between the two time points in the number of optional steps compared to the number of low content elements (n = 43).

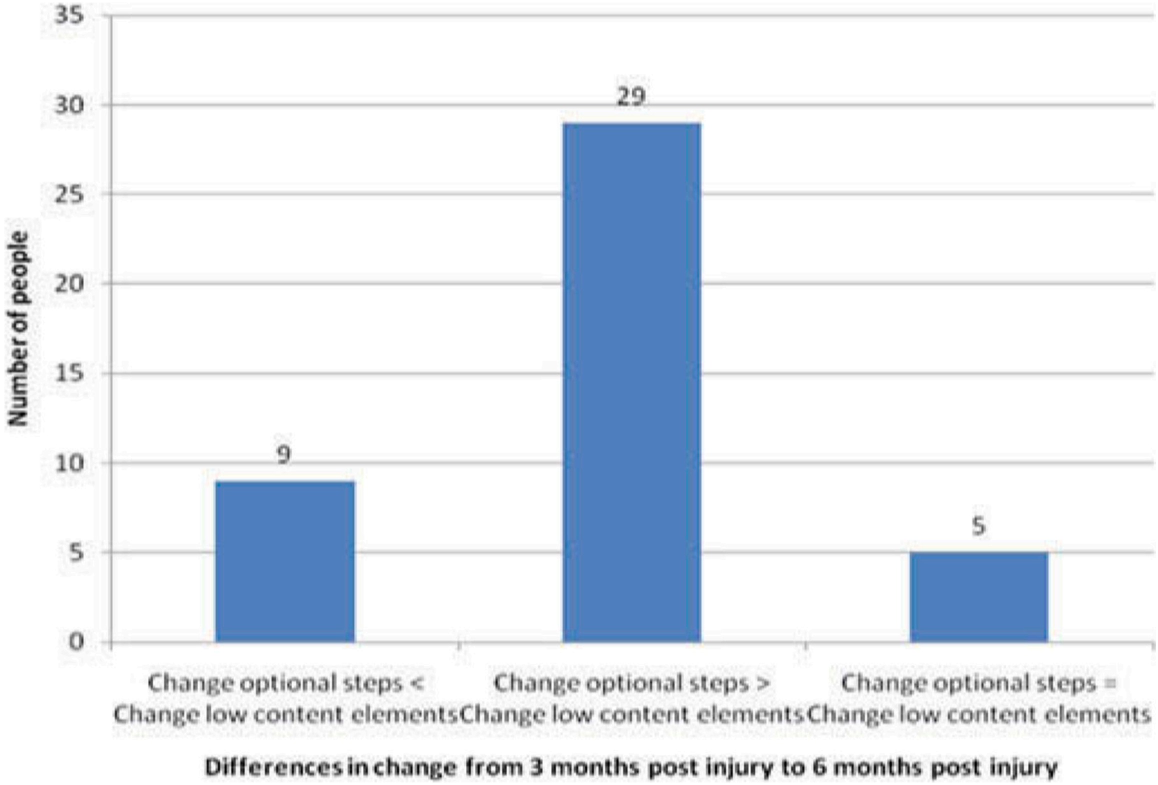

Figure 2.

Rank distribution of the changes in optional steps and low content elements from 3 to 6 months post injury ($n = 43$).

Table 1.

Background information of participants with severe TBI.

Subject	Age	Gender	Education years	[a] Cause of injury	GSC lowest	PTA days	[b] WAB, AQ 3 months	[c,d] Aphasia severity 3 months	Aphasia type 3 months	Dysarthria 3 months	[e] FDA, total speech score 3 months	[f] Speech therapy 3 months	[d] LCQ self 3 months	[d] LCQ other 3 months
1	42	M	12	Fall	4	109	88.5	Mild	Anomic	Yes	92	1.6	53	41
2	39	M	17	MVA	9	45	99.2	N		Yes	118	1.3	55	51
3	23	M	16	Train	8	26	97.6	N		No	131	N	52	58
4	45	M	17	MVA	4	122	91.8	Mild	Anomic	Yes	121	1.1	51	61
5	17	F	12	MVA	3	63	95.3	N		Yes	103	1.8	52	49
6	45	M	11	MVA	9	13	97.9	N		Yes	126	1	69	49
7	28	M	17	MVA	3	86	91.5	Mild	Anomic	Yes	108	4.4	47	65
8	46	M	16	MVA	9	47	92.4	Mild	Anomic	Yes	120	1.8	52	49
9	54	M	13	MVA	10	18	95.9	N		Yes	124	2.9	55	50
10	33	F	10	MVA	5	103	80.3	Mild	Anomic	Yes	87	1.2	54	72
11	24	M	16	MVA	6	25	95.3	N		No	131	2	51	52
12	43	M	10	Assault	5	3	91.3	Mild	Anomic	Yes	96	0.8	58	N/A
13	53	F	20	MVA	7	65	92.6	Mild	Anomic	No	132	2.4	54	50
14	42	M	12	MVA	8	28	100	N		Yes	127	N	51	N/A
15	26	M	18	MVA	8	44	93.6	Mild	Anomic	Yes	127	1.3	48	60
16	67	F	19	MVA	4	50	84	Mild	Anomic	Yes	124	1.7	55	56
17	28	M	15	MVA	3	64	90.9	Mild	Anomic	Yes	103	1.2	49	52
18	40	M	15	Fall	8	48	100	N		No	128	2.6	62	57
19	43	M	12	Assault	8	42	93.4	Mild	Anomic	Yes	124	1	59	62
20	26	M	13	MVA	6	29	N/A	N/A		Yes	117	1.4	48	46
21	67	F	16	MVA	5	102	84.5	Mild	Anomic	Yes	123	1.1	53	79
22	59	M	8	Assault	13	42	N/A	N/A		Yes	121	0.5	47	46
23	49	F	20	Gunshot	9	20	92.4	Mild	Anomic	Yes	95	3	35	61
24	20	M	12	MVA	7	32	93.2	Mild	Anomic	Yes	126	2.7	61	N/A
25	41	M	17	MVA	4	55	86.3	Mild	Anomic	Yes	127	3.2	71	59

Subject	Age	Gender	Education years	[a]Cause of injury	GSC lowest	PTA days	[b]WAB, AQ 3 months	[c,d]Aphasia severity 3 months	Aphasia type 3 months	Dysarthria 3 months	[e]FDA, total speech score 3 months	[f]Speech therapy 3 months	[d]LCQ self 3 months	[d]LCQ other 3 months
26	18	M	13	MVA	3	47	91	Mild	Anomic	Yes	123	1.7	52	51
27	44	M	13	Fall	13	19	92.5	Mild	Anomic	No	130	N	46	49
28	32	M	16	Assault	3	34	97.1	N		Yes	127	N	56	6
29	40	M	17	MVA	3	83	88.6	Mild	Anomic	Yes	108	1	52	82
30	29	M	11	MVA	14	14	97	N		Yes	122	N	57	25
31	18	M	11	MVA	3	28	92.8	Mild	Anomic	Yes	120	0.3	61	48
32	21	M	16	Fall	4	62	50	Severe	Broca	Yes	112	7	N/A	73
33	37	F	12	MVA	5	39	96.4	N		Yes	127	1	54	49
34	23	M	10	MVA	3	90	92.1	Mild	Anomic	Yes	69	0.5	45	83
35	20	M	10	MVA	4	74	87.1	Mild	Anomic	Yes	120	1.2	75	57
36	48	M	10	Fall	8	14	95	N		Yes	129	1	66	69
37	21	M	11	Fall	6	16	94.8	N		Yes	102	2	50	43
38	18	M	13	Fall	6	48	92	Mild	Anomic	Yes	122	N	59	77
39	53	M	15	Fall	8	6	95	N		No	135	2	63	97
40	28	M	16	Assault	14	27	96.6	N		Yes	133	1occ./w[c]	58	50
41	19	F	13	MVA	3	16	96.2	N		Yes	124	2occ./w[c]	46	52
42	38	M	20	MVA	4	38	95.4	N		Yes	122	3.6	53	59
43	49	M	17	MVA	7	41	88.5	N		Yes	124	2	52	58

[a]MVA = motor vehicle accident.

[b]Western aphasia battery, aphasia quotent.

[c]N = non-aphasic.

[d]N/A = not available.

[e]Frenchay dysarthria assessment.

[f]Occasions of speech therapy services/week.

Table 2.

Means and SD or medians, range and inter-quartile range for raw scores on productivity measures and macrostructural measures.

	Control (n = 37)		TBI 3 months (n = 43)		TBI 6 months (n = 43)	
Variables	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Productivity						
Words	84.2	35.7	72.8	47.2	67.3	36.1
Utterances	10.3	4.1	8.9	4.7	8.5	3.2
Speaking time	29.3	12.9	35.6	18.7	33.3	17.1
Words/utterance	8.4	2.4	7.9	2.4	7.7	2.5
Words/second	2.9	0.6	2.1	0.7	2.1	0.6
Macrostructure						
Essential steps[a]	6	0 (6–6)	6	0–6 (5–6)	6	3–6 (5–6)
Optional steps	7.5	3.6	3.6	2.5	4.4	2.4
Low content elements[a]	0	0–4 (0–1.5)	1	0–11 (0–3)	1	0–8 (0–3)

[a]Median, range and (inter-quartile range) is presented due to skewed distribution.

Table 3.

Statistical results for between group comparisons and within group comparisons on productivity measures and macrostructural measures.

Variables	Control vs. TBI 3 months t (df = 78)	Control vs. TBI 3 months p	Control vs. TBI 6 months t (df = 78)	Control vs. TBI 6 months p	TBI 3 months vs. TBI 6 months t (df = 42)	TBI 3 months vs. TBI 6 months p
Productivity						
Words	0.98	0.331	1.88	0.064	0.89	0.379
Utterances	1.25	0.215	1.96	0.054	0.53	0.602
Speaking time	−1.97	0.052	1.4	0.166	0.73	0.469
Words/utterance	0.65	0.520	1.12	0.266	1.04	0.305
Words/second	6.26	<0.001 *	6.78	<0.001 *	−0.49	0.961
Macrostructure						
Essential steps [a]	−4.4	<0.001 *	−4.41	<0.001 *	−1.55	0.146
Optional steps	5.71	<0.001 *	4.63	<0.001 *	−2.29	0.027
Low content elements [a]	−2.93	0.003 *	−2.1	0.032	−1.33	0.183

* Significant result (within group measures $p < 0.0056$, between group measures $p < 0.0063$).

[a] z-value is presented due to the use of non parametric tests.