Following the Conversation: Impacts of Set-Shifting and Topic-Shifting in Healthy Adults and Individuals with Traumatic Brain Injury

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Abstract

Difficulty in conversational discourse abilities, marked by issues with processing topic structure, are a common characteristic of cognitive-communication disorders in individuals with traumatic brain injury (TBI). Despite progress in foundational word and sentence-level skills through speech therapy interventions, problems with conversational discourse tend to remain persistent. This persistence suggests a gap in understanding how non-linguistic cognitive processes influence conversation. In this set of experiments, I test whether cognitive mechanisms related to set-shifting contribute to processing topic shifts in conversation. The purpose of Experiment 1 was to determine if topic switches show characteristic behavioral signatures of set-shifting that emerge in non-linguistic tasks: longer response onset latencies and decreased information content efficiency. The results from the first experiment showed no differences between responses to new topics and the same topics for these measures; however, it was unclear whether these results would reflect responses to shifts in naturalistic conversation or if they simply were products of the experimental design. In Experiment 2, I examined the impacts of the topic switches in naturalistic conversation on language production in healthy adults and TBI patients. This includes measuring productivity, semantic complexity, semantic complexity, syntactic complexity, and fluency for responses to new topics and the same topics. I found that topic shifts elicited costs in terms of the number of words per utterance, verbs per utterance, revisions/rephrasing, and filled and unfilled pauses per syllable for both groups. These findings demonstrate that there are costs associated with switching topics that mirror non-linguistic shift costs, and may suggest they arise from similar mechanisms.

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Introduction

Cognitive-Communication Disorders in Traumatic Brain Injury

According to the Center for Disease Control and Prevention (CDC), every year approximately 1.5 million people in the United States sustain a traumatic brain injury (TBI). A TBI can occur when an object penetrates the skull or a sudden, external force to the head results in damage to the brain. Unlike the focal damage resulting from something like a stroke, in closed-head injuries, the tendency of the brain to jostle back and forth and/or rotate inside the skull typically causes a variety of widespread injuries that impact the connections between various parts of the brain. These disruptions in the communication between neural networks often result in issues with higher-level cognitive functions; for example, coordinating behavior across domains (Dinkel et al., 2014; Kinnunen et al., 2011; Wang & Li, 2016). Due to the nature of this pathology, cognitive impairments are one of the most common complications following a TBI and also one of the most persistent over time (Wang & Li, 2016)

An estimated 80-100% of TBI cases result in cognitive-communication disorders: impairments in communication due to underlying problems in cognition (Macdonald, 2017). The ability to successfully engage in conversational discourse is a hallmark area of difficulty for cognitive-communication disorders in TBI patients. Characteristics of conversational difficulties in TBI include problems conveying information that maintains the global topic structure, providing inappropriate amounts of information, and relying on conversational partners more often to initiate new topics of discussion (Coelho, Liles, Duffy, & Clarkson,1993; Coelho, Ylvisaker, & Turkstra, 2005; Snow, Douglas, & Ponsford,1997; Hill et al., 2018). Because the ability to successfully engage in conversation plays a large role in occupational and social

settings, these difficulties are associated with reported feelings of isolation, challenges in the workplace, and overall decrease in quality of life post-injury (Salas et al., 2018; Lê, Coelho, & Fiszdon, 2022).

Speech-language pathologists (SLPs) often work with the TBI population to improve language and discourse skills. The latest evidence-based speech therapy techniques primarily focus on functional, social, and linguistic factors (e.g., word-finding) that contribute to overall communication abilities. For example, the INCOG 2.0 guidelines for rehabilitation following TBI emphasize personal goals for the patient, applicability to daily activities and life contexts, inclusion of caregivers, incorporating communication partners, compensatory strategies, emotional regulation, social skills, and periodic reassessment based both on standardized tests and performance in functional activities (Theodore et al., 2022).

Despite notable gains in word and sentence-level abilities from speech therapy interventions, conversational impairments secondary to TBI tend to persist along with cognitive deficits (Coehlo, 2007). Additionally, it has been shown that therapeutic approaches that aim to specifically improve cognitive skills are unsuccessful in translating gains in general cognitive abilities to cognitive-communication-related abilities like conversation (Henderson, Roeschlien, & Wright, 2020; Novick et al., 2014). Currently, interventions are constrained by the limited understanding of what specific conversational discourse skills require direct involvement of non-linguistic cognitive processes as well as how specific cognitive deficits in TBI impact particular aspects of language.

In order to understand linguistic and non-linguistic interactions in conversation, I will examine a subset of cognitive abilities with a theoretical overlap with certain conversational abilities. Past work on conversation in TBI patients has provided some correlational evidence for

the relationship between working memory, attention, and set-shifting deficits and discourse structuring; however, these correlational approaches are often imprecise and sometimes contradictory (Hill et al. 2018; Lê et al. 2012). In these studies, I will explore whether a particular cognitive process related to switching between tasks in non-linguistic domains is involved in switching between topics in conversation. The purpose of these studies will be to gain additional insight into the possible relationship between known problems flexibly shifting behavior among the TBI population and problems surrounding the ability to shift between discourse structures. The findings could promote the development of a more full scope of conversational discourse interventions by addressing the underlying non-linguistic issues that contribute to the linguistic presentation.

Cognitive Set-Shifting

Set-shifting can be described as the ability to flexibly shift between representations and processes needed to perform complex tasks or action sequences (the set). The time spent in a set and the decision to switch is often goal-directed. For example, in order to do any particular job, there may be a set of relevant sub-tasks one must complete; for instance, answering the phone. For this set, one might need to allocate mental resources to processes related to auditory perception, conversation, motor coordination, etc. When switching the tasks to, let's say, answering an email, these mental resources must be reconfigured to accommodate additional activation for processes related to reading, visual integration, etc. while other processes, like auditory perception, may not be as necessary. Being in a *set* means that certain representations are made more readily available according to whether they are relevant to the requirements of the task at hand.

One common paradigm used to test set-shifting in an experimental setting involves a task-cueing procedure such as in Mckewen et al. (2020). In this setup, participants are given binary options for responses for three different possible tasks. A cue for the current task and the target stimulus are presented sequentially on each trial and then the participant is given the opportunity to respond. In set-shifting paradigms like this one, the availability and recency of previous set representations impacts the execution of the current task (Frings et al., 2020; Monsell, 2003). Behaviorally, this is reflected by longer response times and reduced accuracy when the task switches versus when the task stays the same (Kiesel et al., 2011; Mckewen et al., 2020; Ravizza et al., 2008).

Chronic deficits in cognitive set-shifting are frequently reported in individuals with TBI. In experimental set-shifting tasks where participants switch between rule sets, TBI patients often show proportionally greater time and accuracy costs on switch trials than healthy adults (Barlow et al., 2018; Perlstein et al., 2006). Set-shifting deficits in TBI patients may also look like struggling to shift between different functional actions; for example, taking an unusually long time or effortful transitions between answering a phone call, grabbing items for customers, and other actions that might be needed in their workplace (Levin, Chum, & Chan, 2014).

There are multiple proposed explanations for behavioral costs when switching. The *task-set inertia* explanation posits that effects are due to difficulty shifting away from persisting representations; therefore, switch costs arise from the interference from the previous set. This is supported by studies that find that delays between tasks, which allow for disengagement from the previous set, decrease switch costs (Allport, 2000; Evans, Herron, & Wilding, 2015). Another account suggests that switch costs arise from the time-consuming reconfiguration of neural resources when the task switches. When provided additional time to prepare for the upcoming

task by receiving a cue for what the task is, performance on switch trials also improves (Rogers & Monsell, 1995; Sohn & Anderson, 2001). *Set reconfiguration* refers to the preparation processes, that upon receiving input that conflicts with the current set, retrieve the goal and/or the task rules and re-organize representations accordingly. This process is hypothesized to occur during the cue-to-stimulus interval (CSI) in task-cueing, set-shifting paradigms. Although there may be disagreement about why switch costs occur, the completeness, or if it's an all or none process, the core process involved in set-shifting and task-switching is relative inhibition of items in the set being shifted from and activation of items that are needed for the current set.

The Binding Retrieval Action Control (BRAC) framework presents a theory for understanding switch costs that integrates various paradigm-specific explanations (Frings et al., 2020). Under the BRAC framework, features of the stimuli, response, and their effects are integrated into an "event-file" through a binding process and are retrieved by the presence of any feature during event coding. This has implications for how costs arise in task-switching/set-shifting paradigms from the prime (trial n-1) to probe (current trial). In the non-linguistic set-shifting literature, it is often proposed that sets themselves are competing. However, the BRAC framework suggests that it is not the higher-level hierarchical information, but the aspects of the event. For instance, in a task-cueing paradigm, the stimulus and the response are bound together in the prime and integrated into the event file. Characteristics of the stimulus from the prime that are repeated in the probe result in the retrieval of the event file from the prime. In cases where the task switches, the stimulus-response mapping of the prime is incompatible with the probe, which generates competition and leads to a cost of switching. This view of set-shifting shows some notable connections to explanations of how shift costs arise when switching between discourse structures.

Below, I will further explain how set-shifting problems in TBI are ostensibly related to the conversational problems that are symptomatic in the TBI population. I will then develop the novel hypothesis that cognitive mechanisms related to switching in non-linguistic tasks are involved in switching topics during conversation.

Conversation

Several of the previously discussed difficulties in conversation among TBI patients are related to topic. Notions of what defines topic are elusive; however, somewhat of an agreement has formed about how proceeding in conversation involves a series of situations where conversational partners maintain the topic or switch between them (Riester, 2019). It is also generally accepted that conversational discourse follows a hierarchical structure. Subtopics are nested under other topics which all connect in some manner to a main topic (Gernsbacher, 1991). For example, in a conversation between reunited childhood friends, one person may start the conversation with something like “Do you remember grade school?” to initiate an overarching topic related to their elementary school experiences. These conversation partners then may talk about classes such as English or Math as subtopics, and as the conversation proceeds, they inquire further about teachers, activities, and classmates related to those specific classes. Similar to discourse structure, goal-driven action sequences outside of the domain of language form a hierarchical structure where certain groups of sub-tasks are relevant to completing larger tasks that ultimately contribute to a common goal, like the earlier functional example about switching tasks in the workplace in order to complete the actions needed to do one’s job (Kahn & Lesperance, 2010; Uddén, Jesus Dias Martins, Zuidema, & Fitch, 2020). Although topics and tasks could be represented similarly due to their hierarchical structure, it is unclear whether

cognitive mechanisms involved in switching between nodes of representation for *tasks* are involved in the switching between *topics*.

Some theoretical work has been done to uncover how interlocutors build discourse structure in real-time. In question under discussion (QUD) theory, conversational partners share a common goal of informational exchange and use questions as a strategy to move the conversation forward. This posits that topic changes are the result of changing the superordinate structure (the question), which constrains upcoming discourse to possible answers. Changes occur when speakers agree to a new question, not because of the characteristics of the answers.

Like the BRAC framework, other views on discourse structure take more of a "bottom-up" approach. The premise of the Structure-Building Framework proposed by Gernsbacher (1990) is that the goal of language comprehension is to form a coherent structure between information. The initial incoming information organizes the mental representation and lays the foundation for the structure. After laying the foundation, subsequent information that is more coherent is mapped onto previous substructures and less coherent information signals a shift to build another substructure. How coherent the input is depends on whether there are clear referential, temporal, lexical, causal, or locational relationships between units. The Structure-Building Framework also states that all incoming pieces of information activate memory nodes which serve as the building blocks of mental structures. Elements of the same structure activate interconnected memory nodes, whereas shifting to new substructures involves the suppression or enhancement of the activation of memory nodes. This is supported by Gernbacher (1985), who demonstrated that information immediately before a shift is harder to access than when actively building a structure. They propose that differences before and after a

shift are accounted for by cognitive processes related to shifting for the comprehension of both linguistic and non-linguistic information.

Topic-Shift Costs

Like cues for tasks in non-linguistic situations, conversational partners can provide cues for upcoming topics. Additionally, receiving a cue that the topic has switched will signal for preparation processes that shift representations in advance of the new topic. During a shift, some elements may be easier to retrieve than others depending on how activated they were in the topic being shifted from. Readily available representations are more relevant when responding to a topic that is the same as the one before it. Conversely, to respond to a newly initiated topic, some persisting information from the previous topic that is no longer useful for the current topic will be inhibited and some information that was relatively deactivated in the previous topic will be activated. Although the relative activation and inhibition of information occurs when shifting in non-linguistic contexts, it is unclear whether shifting in discourse requires the same time- or resource- consuming cognitive processes. Also, there is no current knowledge about which level of planning a topic shift would impact. The downstream effects of increased processing demands on comprehension from the need to do this reconfiguration during a topic-switch could delay any combination of subsequent motor-speech, message-level, or syntactic planning which inevitably impacts production.

The Current Study

The experiments in the current study aim to fill a critical gap in knowledge about how specific non-linguistic cognitive processes underlie aspects of conversational discourse which is

motivated by a theoretical overlap among task-switching and topic-switching. Through this, I hope to develop a mechanistic understanding of the relationship between prevailing descriptive accounts of TBI including topic-related conversational impairments and chronic set-shifting deficits. Specifically, I seek to determine if neurocognitive mechanisms related to set-shifting are involved in switching topics during conversation. This includes understanding the effects of processing a change of topic in real-time conversation for both TBI patients and healthy adults.

The purpose of Experiment 1 was to determine if processing a topic-switch involves cognitive mechanisms related to set-shifting. I tested the hypothesis that topic switching during conversation shows behavioral hallmarks of set-shifting by examining if there are response time and efficiency costs associated with switching in healthy adult participants. This was done via isolating the switching component through a semi-structured conversational exchange where the experimenter guides the topic structure. To do this, I used a task-cueing paradigm adapted for conversation.

However, unlike tightly controlled non-linguistic task-cueing paradigms such as the previously mentioned Mckewen (2020) procedure, topics are not simple stimulus-response mappings among two possible decisions, and responses to questions can vary in a number of ways depending on things like world knowledge and lexical access which are highly individualized. Although a semi-structured exchange only containing explicit topic cues may not capture some crucial aspects of conversation, it allows us to better control for important time intervals through a methodological approach to cue and stimulus presentation as well as mitigate the variability of participant responses by constraining topics to generally shared experiences. Moreover, it minimizes confounding sources of costs that may have been present in the context of a naturalistic conversation.

There are several task-specific costs that have been identified in the non-linguistic set-shifting literature that I took into consideration for the experimental design. In a study by Mayr & Keele (2000), switching from a task to a new task and back to the original task elicited greater behavioral costs than switching to three separate tasks. This suggests that disengagement from a prior set involves persistent inhibition. We avoided effects of residual inhibition of previous topics that may emerge in 3-set tasks by eliminating instances where topics immediately switched back to a previous topic (e.g., topic a - topic b - topic a).

Another account from Logan and Bundsen (2003) is that differences in performance are from cue-encoding benefits on trials where the task is repeated. In task-cueing procedures that use a single cue for the same task, there are notable priming effects for successive stay trials. Therefore, they argue that costs are a result of the contrast between the greater processing demands and the time it takes to encode cues on switch trials compared to stay trials for which the cue is primed, rather than the time to complete processes like conflict detection and set reconfiguration. To lessen priming effects, I use two different types of cues per topic that are counterbalanced across participants; therefore, participants are less likely to be accustomed to specific cues.

Additionally, switch frequency has been shown to play a role in the emergence of switch costs. When the probability of task switches is lower, the resulting behavioral costs become larger. Alternatively, increasing the frequency of switches reduces switch costs. Logan and Schneider (2006) explain that this effect is either from cues for the next trial being automatically primed according to the relative amount of the types of switches stored in memory, which is greater for experimental tasks with frequent transitions, or that sensitivity to the frequency of switch-cues causes strategic priming where certain cues increase the expectation that a cue for a

switch will occur. In contrast, Monsell & Mizon (2006) and Mayr (2006) found that there are costs over and above the costs of cue-switching and that strategic priming is not cue-specific. Instead, they found that expectations of switch probability are formed from the sensitivity to the overall probability of a task switch and that reasonably decreasing the probability of switching can help constrain set reconfiguration to the trial cue. However, for a switch probability that is too low, there can be a cost of surprisal from the appearance of a switch violating preconceived expectations that are skewed toward task repetitions. Hence, in line with moderate switch-stay trial probabilities from these studies, the switching frequency is 40% and the repetition frequency is 60% in Experiment 1. This along with having multiple cues and limiting certain types of switches allowed us to curate materials that isolate switch costs to the best of our ability despite the complex nature of conversation.

Overall, Experiment 1 aimed to probe whether topic-switching requires set-shifting processes. If there are behavioral costs of set-shifting when topic-switching, it would suggest that similar cognitive mechanisms support shifting in non-linguistic situations and in conversational discourse. Taken together with Experiment 2, these results could further our knowledge of the relationship between deficits in set-shifting and difficulties shifting topics in the TBI population.

The goal of Experiment 2 was to narrow down hypotheses of how processing topic-switches impacts language production in both healthy adults and TBI patients in naturalistic conversation. Comprehending discourse requires multiple levels of comprehension from the surface code to pragmatic communication (Graesser & McNamara, 2011). The breakdown at one discourse level can have a substantial impact on performance at other levels. Studies of topic in TBI often focus on macrolinguistic indicators of comprehension; for instance, how well individuals with TBI can generate responses that cohere with the present topic, and the

overall topic of conversation (Coelho, Liles, Duffy, & Clarkson,1993; Coelho, Ylvisaker, & Turkstra, 2005). However, it is unknown if and how responses differ within topics and proceeding a topic-switch on micro-linguistic features on the receiving end of a topic-switch. Although there is some theoretical evidence for topic being related to conceptual representations, which would likely affect semantic content following a topic switch, the understanding of the actual representation of topic is still largely unknown; thus, it is difficult to make precise predictions that can inform what shift costs mean in the context of conversation (Taboada & Weisemann, 2009). Experiment 2 aimed to reveal what aspects of language processing are sensitive to being a "receiver" of a topic shift. The results from Experiment 1 will motivate further exploration of the relationship between shifting topics and cognitive processes that facilitate shifting across domains.

Research Questions

In order to better understand the involvement of non-linguistic processes in conversation and its relationship with conversational impairments secondary to TBI, this study will address two main questions:

1. Are neurocognitive mechanisms for set-shifting involved in topic-shifting during conversational discourse?
2. How does being on the receiving end of a topic-shift impact language production in both healthy adults and individuals with TBI?

Experiment 1

Here, I test whether participants display behavioral signatures of set-shifting when processing a change in topic. I hypothesize that participants will take longer to respond and responses will have reduced informational content efficiency when the topic switches compared to when the topic stays the same. Experiment 1 tested healthy adults to inform future designs to test similar hypotheses in TBI patients.

Methods

Participants

Twenty-seven healthy adults (mean age= 19.3 years; age range=18-22 years) from the University of Maryland community participated in Experiment 1. All participants who completed the study were native English speakers, had normal or corrected to normal vision, normal color vision, normal hearing, no history of speech, language, or attention disorders, and no history of neurological disorders. Participants were compensated via *SONA* course credit for the University of Maryland, College Park.

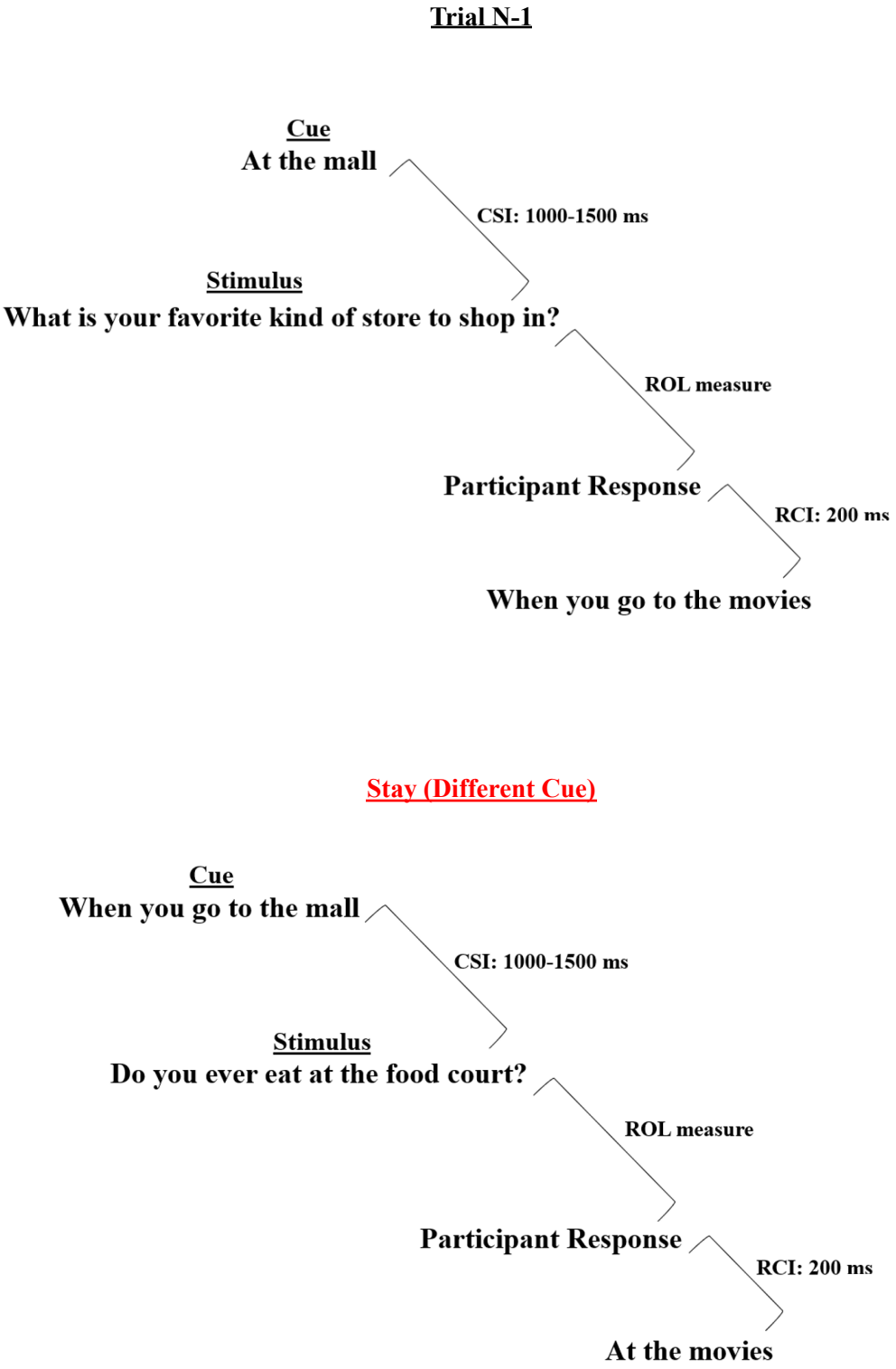
Materials & Design

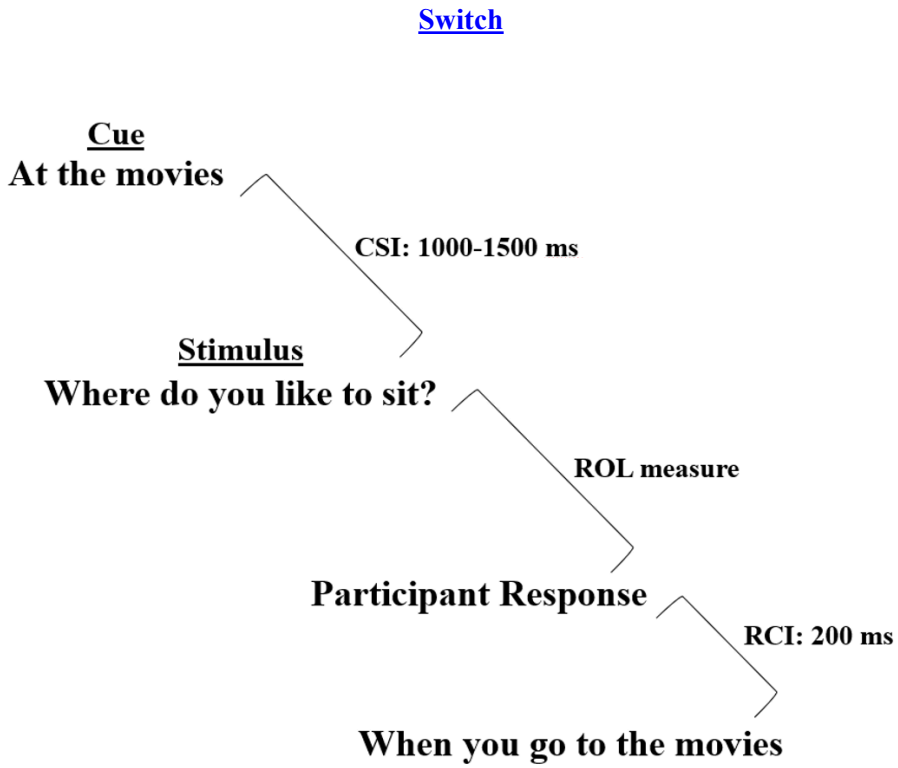
Before starting the semi-structured conversation, participants previewed each of the questions individually to pre-activate ideas for responses. Then, participants gave original responses to scripted questions asked by one of the two possible experimenters. Participants were instructed to answer questions in one to two sentences and provide additional details for their answers. There were six main topics of conversation that corresponded with the six trial blocks. Trial blocks consisted of fifteen questions that switched between three different possible subtopics (see Figure 1 for schematic). The current topic and subtopics were visible to

participants throughout the experiment. Experimenters were guided by a screen that displayed the cue and then question for each respective trial. Individual trials consisted of a cue for a sub-topic (*e.g.* "During the *birthday party*…") followed by an approximately 1000ms[1] CSI and the question (*e.g.* "...Did you sing?). After the participant responded, there was 200 ms, response-to-cue interval (RCI) before the next trial. The order of the questions determined if the sub-topics switched (*e.g. birthday party* → *graduation*) or stayed the same as the one before it. The first trial in any given block was a filler that was neither a switch nor a repetition of the topic. There were four possible lists of questions that were counterbalanced in respect to whether a certain question was a switch or stay as well as the type of cue (*e.g.* "When you go to the mall…" vs. "At the mall…"). In each list, the topic switched 40% of the time and the topic was the same 60% of the time.

[1] I originally programmed the question to appear on the screen 500ms after the cue. The time taken to read the question may have delayed us saying the question aloud thus, increasing the length of the CSI to approximately 1000-1,500ms.

Figure 1. Schematic of Procedure





Data Analysis

I measured response times and content for responses to determine if there are hallmark behavioral effects of set-shifting when switching topics. Recordings of participant responses were converted to speech waveforms using PRAAT (Version 6.4; Beorsma & Weenink, 2023). I then inserted tiers for the starting and ending boundaries to segment response waveforms and extracted durations. The response onset latency (ROL) measures[2] included the time from the end of the question to the first vocalization and the time to the start of the response excluding fillers. Additionally, I transcribed participant responses using MacWhisper automated speech recognition software and checked transcriptions manually. I used Computerized Propositional Idea Density Rater (CPIDR) version 3.2 developed by Brown et al. (2008) to measure

[2] Mean ROL including filled pauses, shown in Figure 2a, became our primary ROL measure because it accounts for planning time.

informational content efficiency by identifying "propositions": key units that assist in comprehending a message (e.g., verbs, adjectives, quantifiers, etc.). Content analyses involved measuring propositions in terms of the quantity per second of response time and the Idea Density (propositions per words).[3] A Welch's two-sample t-test comparing mean performance on stay trials and switch trials was conducted in R-studio (Version 3.2; R Core Team, 2023).

Results

On average, the ROL to the first vocalization on switch trials (*M*=1060 ms) did not differ from stay trials (*M*=1080 ms; p=0.34) (not depicted in Figure 2). As seen in Figure 2A, mean ROL including filled pauses was more distinct between instances when the topic stayed (*M*=1250 ms) and switched (*M*=1290ms). However, this difference was also not significant (p=0.21). Moreover, in our content analyses, the average number of propositions per response (Figure 2B) time did not differ in switch (*M*= 1.99) and stay trials (*M*= 2.04; p=0.76), which is best observed in Figure 2B. There was also no significant difference in the Idea Density measure (Figure 2C) between stay (*M*=0.49) and switch trials (*M*=0.50; p=0.338).

[3] Content analyses were only performed on data from the first twenty-seven participants.

Figure 2a. Onset Latency for Responses Including Filled Pauses

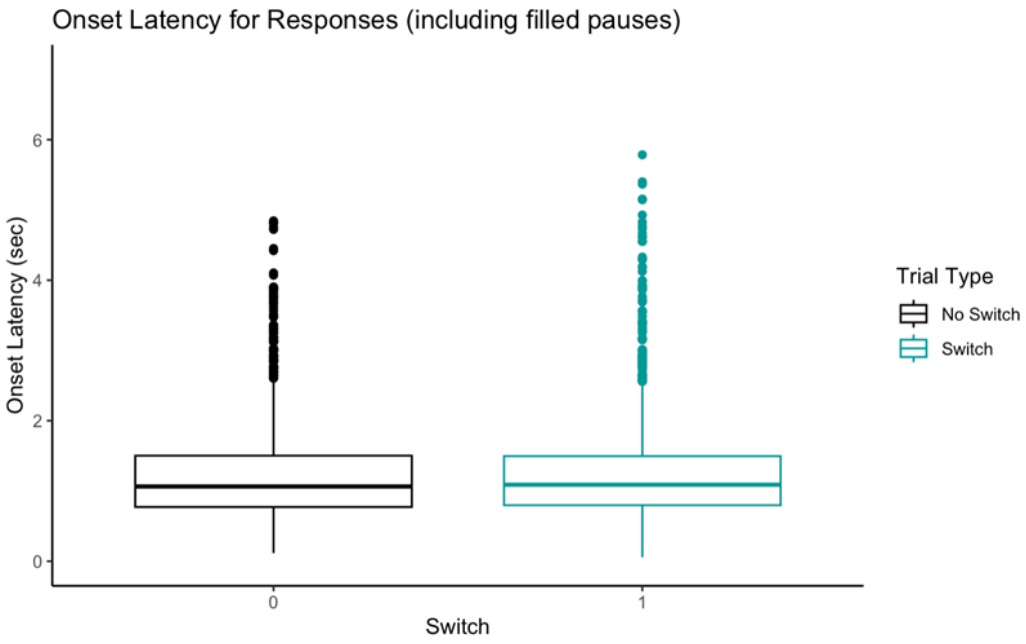


Figure 2b. Idea Density for Responses

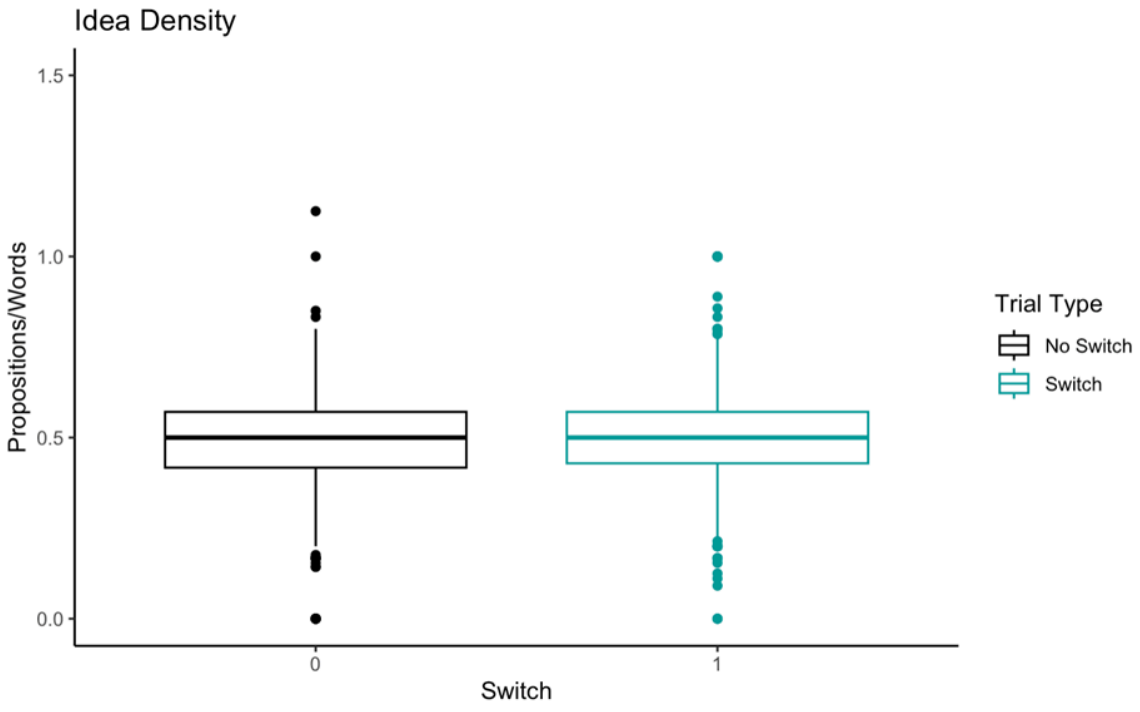
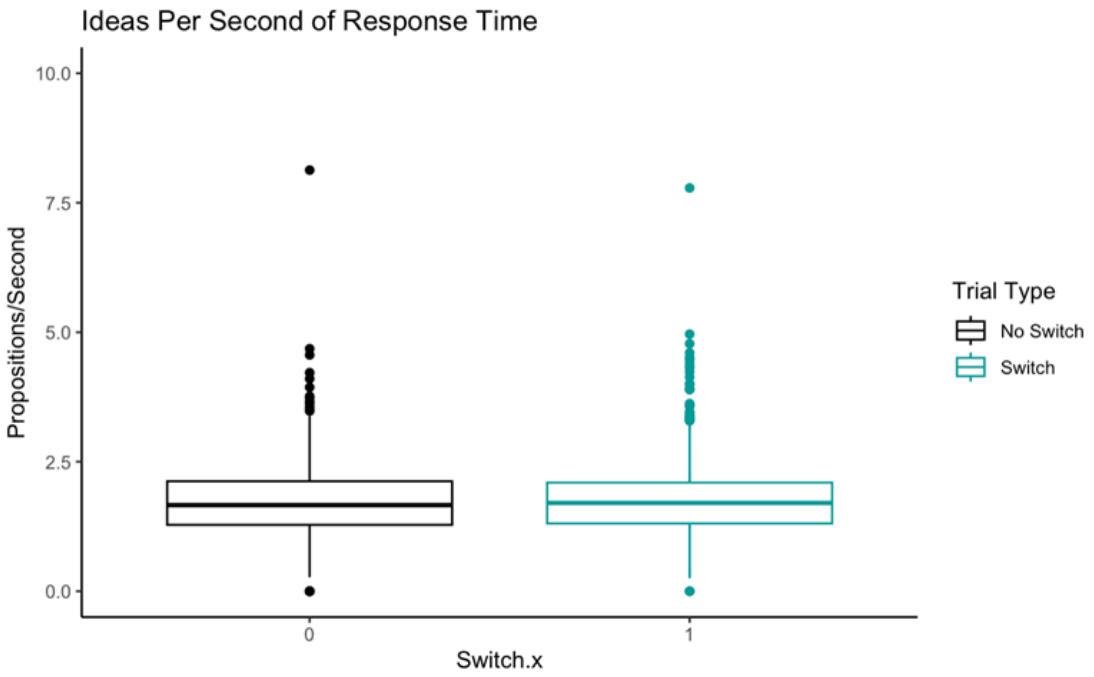


Figure 2c. Ideas per Second of Response Time



Discussion for Experiment 1

Given there were no statistically significant differences in our speed and efficiency measures for responses to topic switches compared to responses to the same topic, the results from Experiment 1 demonstrate that participants did not show behavioral signatures of set-shifting during topic-switching in conversation. The absence of shift costs could indicate that set-shifting is not involved in the conversation or that the structure of conversational discourse is different than that of sets. It also could be that conversational discourse appears hierarchically structured post-conversation, but interlocutors are unaware of the structure in real-time.

However, other potential factors from the experimental design may have influenced the presence of behavioral effects. First, there were notable temporal differences between the

presentation of the cue and the question as well as the opportunity to respond in this experiment when compared to similar non-linguistic set-shifting tasks. Namely, in non-linguistic set-shifting tasks, the presentation of a visual stimulus like a number or a singular word, takes several hundred milliseconds less than listening to a spoken question. Moreover, although the CSI was originally programmed to be 500ms[4], the time to process, read, and say the question out loud resulted in the time between the cue and the question to be approximately 1,000ms on average. This increased distance between the CSI and when a response is possible may have been too large to detect shifting costs in the time window where it would have occurred.

Second, complex linguistic tasks such as conversation require the involvement of many different linguistic and non-linguistic processes that are difficult to distinguish in a behavioral task. For instance, on same-topic trials in this experiment, a cue is provided for the previous question and the current question whereas in naturalistic conversation, the topic is not typically introduced when remaining on the same topic. Because receiving these cues is somewhat infelicitous, there may be potential costs associated with expectation violation when encountering this particular artifact of the experimental design in the opposite direction of shift costs. Furthermore, previous work has shown that demands on other cognitive systems impact conversational success or responses to shifting. For example, the need to attend to cues occurs before the need to shift sets. It is possible that engaging cognitive mechanisms related to attention may be the prominent issue for topic-shifting problems observed in the TBI population as well as any minute changes in performance when processing topics for healthy adults. Additionally, when moving through conversation, listeners must hold information from their conversational partner's response in order to integrate current information with relevant prior

[4] There was variability in the CSI. The timing for cues and questions were provided by a screen for which experimenters read in fron of the participant to keep the experiment conditions as naturalistic as possible.

information and produce a response of their own. For individuals with TBI, working memory has been shown to be a significant predictor of discourse comprehension (Lê, Coelho, & Fein, 2023). In non-linguistic set-shifting paradigms, performance on stay trials is decreased when there are shift trials mixed with stay trials compared to when there is no need to shift (Monsell, 2003). These "mixing costs" are generally associated with continuously having to manipulate items in working memory and using the held information to inform responses. The combination of these various confounding factors may also result in shift costs not only being difficult to detect but also isolate.

To address these concerns, a follow-up study using time-sensitive electroencephalography (EEG) methods would be useful in distinguishing between the involvement of set-shifting among other processes involved. Recent studies have used EEG to determine the neural processes activated by shifting through recording neural oscillations via electrodes on the scalp. Neural oscillations are rhythmic patterns of electrical brain activity that reflect the coordination of information processing among neuronal assemblies from different parts of the brain. ERPs are electrical brain activity averaged across the EEG signal that is associated with a particular event. ERP waveforms consistently show cue-locked prolonged parietal positivity on switch trials across various cued experimental set-shifting paradigms (Barceló & Cooper, 2018; Cunillera et al., 2012; Karayanidis, 2010; McKewen et al., 2020; Periáñez & Barceló, 2009). Apart from ERPs, other neurophysiological signatures of set-shifting can be found in time-frequency analyses of EEG which show significantly greater mid-frontal power in theta band oscillations on switch trials compared to stay trials. Such theta power bursts in EEG are brief increases in oscillatory amplitude for frequency components in the range of 4-7Hz (Astle, Jackson, & Swainson, 2006; McKewen et al., 2020). Future work looking for these

theta power differences in healthy adults would allow us to reveal more fine-grained neurophysiological effects from topic-shifting and isolate set-shifting among other possible processes.

Not only can EEG reveal whether set-shifting is involved in topic-switching in healthy adults, but it can also show differences in neurophysiological responses to shifting for those with known set-shifting deficits. Healthy adults appear to navigate topic shifts with ease in everyday conversations. It could be that there were no behavioral costs of shifting in this task because neurologically healthy adults are adept at navigating topics. In accordance with expectations from behavioral presentations of set-shifting deficits in TBI, a study by Barlow, Medrano, Seichephine, and Ross (2018) found that TBI patients demonstrate not only proportionally greater behavioral costs when task-switching but also greater disruptions in signature theta oscillatory activity compared to healthy adults. Future research could examine whether there are greater neural signatures of set-shifting when topic-switching during conversation for TBI patients than for healthy adults.

In Experiment 2, I turn my attention to impacts on language production from being a "receiver" of a topic-shift in not only healthy adults, but individuals with TBI. Overall, in terms of clinical relevance, the primary concerns for functional communication for TBI patients experiencing increased difficulty in conversation from shifting would be the linguistic outcomes. While measures like ROL may help decipher the theoretical tie between non-linguistic and topic-shift costs, effects on linguistic outputs like idea density or disfluency are the factors that may be noticeable to conversational partners.

In Experiment 1, I test semantic complexity following a topic shift through Idea Density and propositions per time in healthy adults. Upon a further look into this particular measure, it

was found that propositional ratings tended to be high for quick, but uniformative responses (*i.e.* "Yes, I did"). These ratings artificially inflated some ratings for utterances within the sample and may have impacted results for our informational content efficiency measure. It could be these measurement considerations contributed to the null finding; however, it is also possible that semantic complexity is not the linguistic level impacted by topic status. Other parameters of language production, such as semantic complexity or fluency, may be impacted by increased demands from shifting. In order to inform future hypotheses about the behavioral costs of shifting between topics in conversation, Experiment 2 examined whether topic status was associated with decreased performance in various measures of language production in not only healthy adults but also individuals with closed-head injuries.

Experiment 2

In Experiment 2, I examine the effect of being on the receiving end of a topic shift on language production in both healthy adults and TBI patients. We did this to determine if other linguistic systems were sensitive to topic-shifts, such as syntax, general planning, and monitoring. Consistent with the hypothesis that topic-shifts will elicit shift costs, I predict that there will be greater disfluencies, less syntactic complexity, and less information content richness for utterances following a change of topic.[5]

Methods

Participants

[5] Although these are our general predictions, I believe it could be any one or combination of these effects. This portion of the study should be considered exploratory as its purpose is to help inform concrete hypotheses for future experiments pertaining to linguistic factors impacted by topic switches.

I extracted data from TBI Bank (https://tbi.talkbank.org) to do a detailed corpus analysis focused on responses to new topics and the same topics. TBI Bank is a database containing compatible media and transcripts of individuals with TBI engaging in conversations as well as other types of interactions in order to examine communication in this population. The Coehlo, Youse, and Lê (2002) cohort contained fifty-five participants with closed-head injuries (mean age=28.6; age range=16-69) and fifty-two healthy, non-brain-injured (NBI) controls (mean age=31.9; age range= 16-53) recruited from rehabilitation hospitals in New York, Rhode Island, and Connecticut. All participants were native English-speaking adults. Healthy controls had normal hearing, normal vision, no psychiatric history, and no history of neurological disorders. TBI participants had normal hearing, normal vision, no appreciable deficits on clinical language tests, no motor-speech impairments, no history of mental illness, and were level VII (Automatic-Appropriate) or above on Rancho Los Amigos Levels of Cognitive Functioning. The time since injury onset varied among TBI participants from 1-99 months, with an average post-onset time of 10.5 months. According to Lezak (1995) criteria, participant injuries were classified as either moderate (loss of consciousness for less than 6 hours) or severe (loss of consciousness for more than 6 hours). The researchers who collected this data assert that they made a reasonable attempt to match groups by age, gender, socioeconomic status, and years of education. As data analysis for this project is ongoing, the current study is based on N=20 participants in each group (NBI, TBI).

Transcripts

All files were in TalkBank Codes for Human Analysis of Transcripts (CHAT) format and transcribed using Computerized Language ANalysis (CLAN) conventions (MacWhinney, 2000).

Files were based on interactions between an experimenter and an individual with TBI or a NBI control. CLAN allowed us to link transcripts to the respective media and perform a wide range of automated computations of standardized language measures.

Procedure

Topic and Subtopic Identification

Within each conversation transcript, two coders (author and graduate student co-advisor) labeled topics and subtopics using separate "@Comment:" headers. Prior to labeling, coders read and listened through the entirety of the conversation for a broad understanding of the general context. Topics and subtopics were determined using a similar method to Leaman and Edmonds (2020). The conceptual framework for finding topics proposed by Leaman and Edmonds (2020) includes a careful identification of what they refer to as "topic-initiation mechanisms" (*see Table 1).* Topic-Initiation mechanisms are ways in which interlocutors naturally signal a shift to a new topic within the conversation.

Table 1. Topic-Initiation Mechanisms

Topic-Initiation Mechanisms	Description	Example
Topic-closing	A routine manner of ending a previous topic which may include a series of turns where no new information is added, wrap-up statements, or pauses greater than one second.	"Yeah, that does sound nice"
Discontinuity Device	Words or phrases used to explicitly indicate that an utterance will include a change of topic	"By the way…"
Cohesion	Responses that appeal to a lexical or referential relationship to the previous utterance and create a logical transition.	Partner A: "I went to the mall with my friends this weekend."

		Partner B: “I went to watch a movie at the theater there Saturday.” Partner: “I love that movie theater.”
Non-coherent comment	A statement that has no logical relation to the previous utterance, but the conversational partner accepts it as a new topic.	Partner A: “I cooked spaghetti for dinner last night.” Partner B: “I hate how it’s so cold out” Partner A: “It’s so freezing I wore three layers of clothes.”

Response Coding

CHAT files consist of main tiers that contain utterances connected to an established three-letter speaker ID. For these files, the “INV” ID corresponded to transcribed utterances from the investigators and the “PAR” ID corresponded to transcribed utterances from the participants. Dependent tiers were inserted directly under the main line to enter codes of interest. Using dependent speech act tiers (%spa:), I created a coding scheme (Table 2) to reference responses in relation to their purpose within the conversational topic structure. Codes began with the dollar sign ($) operator which allowed for the extraction of main tiers with specific codes.

Within the accepted topic boundaries established by topic-initiation mechanisms, conversational partners maintain the topic by attempting to form responses that connect to utterances before it (Sacks, Schegloff, & Jefferson, 1973). Therefore, utterances in conversation can either function to initiate new topics, respond to new topics, or respond in coherence with the same topic. These possible functions were accounted for in our coding framework with respect to

the speaker. Also, there are situations where responses to a conversational partner do not contribute meaningfully to the discourse. If someone responded with a non-coherent comment and the conversational partner continued with the current topic, I considered their utterance off-topic and coded it as such. I coded all the utterances within a turn with the same code, unless some part of the turn was off-topic. Additionally, verbal feedback that seemed to serve no other purpose than to indicate that a person was paying attention to their conversational partner (e.g., “mmhm”, “oh”) was coded as a backchannel in order to distinguish them from meaningful responses.

Table 2. Speech act codes

Code	**Meaning**
INEW	Investigator started a new topic
PNEW	Participant started a new topic
IPNEW	Investigator response to a new topic utterance
PINEW	Participant response to a new topic utterance
IPSAME	Investigator response to an utterance of the same topic
PISAME	Participant response to an utterance of the same topic
IOFF	Investigator is off-topic
POFF	Participant is off-topic
BACK	Backchannel

Reliability

Interrater coding reliability for each item was calculated using the RELY command on CLAN. The two raters completed training on and made adjustments to the coding protocol until reaching an 80% agreement among raters for two consecutive files. Reliability was calculated at

a frequency of every tenth file which equated to ~10% of 100% of the files used in the sample. The average Cohen's Kappa for training files was ~0.7. According to McHugh (2012), Cohen's Kappa results in the range of 0.61-0.81 taken together with ⩾80% agreement indicate substantial reliability.

Data Analysis

Using the COMBO command in CLAN, I limited transcripts to subset participant responses to new topics and responses to the same topic. Separate CHAT files were created for each type of response. Before calculating a number of language analysis computations, CLAN requires the use of the MOR program. I ran *mor *filename.cha* to create a %mor lines containing part-of-speech analyses for each word.

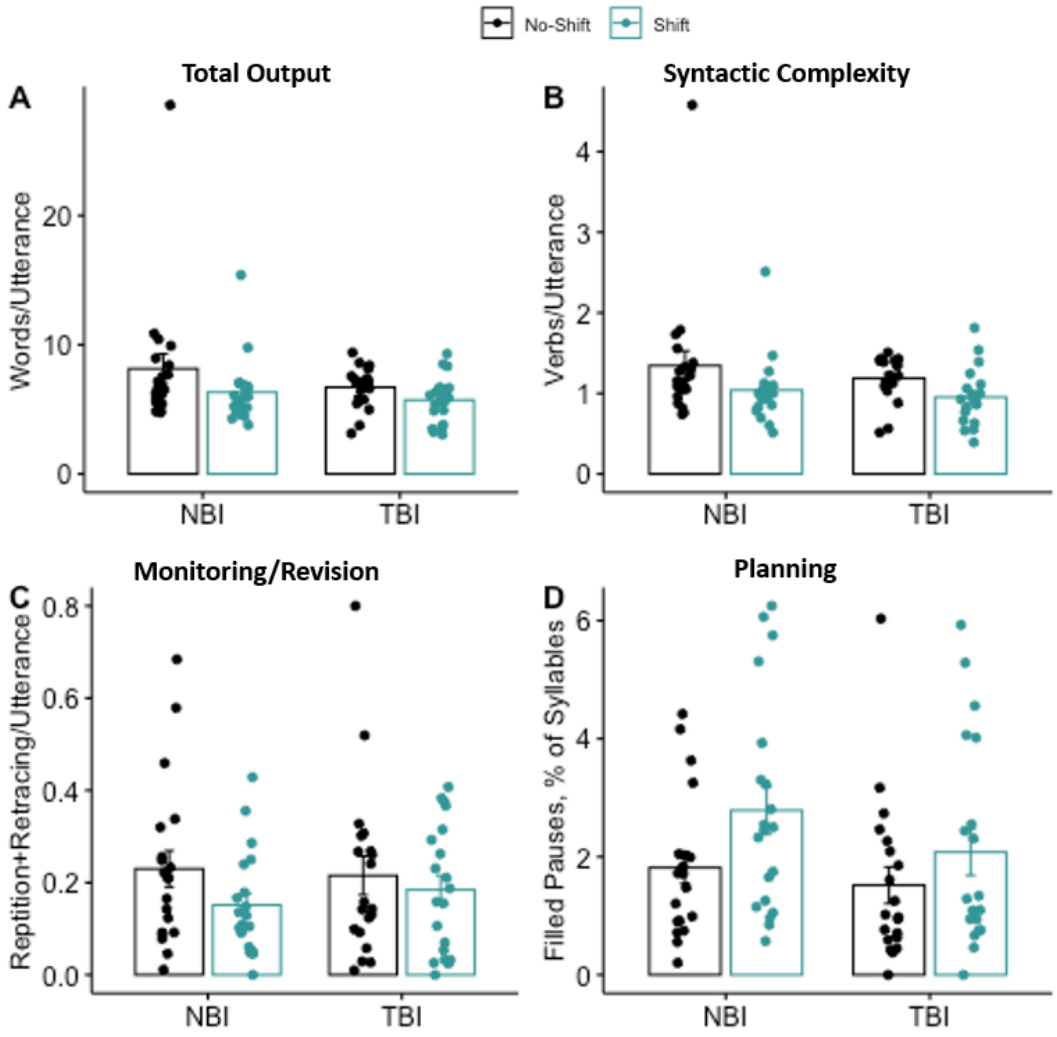
Profiling commands ran on each file included FluCalc, Developmental Sentence Score (DSS), Eval-D, and Sampling Utterance and Grammatical Utterances Revised (SUGAR). Utterances were transcribed with markers of disfluency according to TalkBank conventions for disfluency transcription. FluCalc, a command that computes typical and stuttering-like fluency indicators, was used to determine the number of typical disfluencies per syllable (Garbarino, Bernstein Ratner, MacWhinney, 2020). SUGAR was used as a measure of sentence complexity. The SUGAR program calculated mean words per sentence and clauses per sentence using a corpus of 50 sentences from the speech samples. Moreover, I performed the EVAL command which uses the AphasiaBank protocol (AphasiaBank (talkbank.org)); Lanzi et al., 2023) to derive a wide range of language characteristics from discourse samples. The primary measures I highlighted from the Eval output were verbs per utterance, words per utterance, the number of retracings and repetitions per utterance, and Idea Density. The Idea Density measure was the

main index of semantic complexity for responses. I used generalized linear mixed effects models to test the effect of topic status (new or same) on participants' subsequent productions across groups, controlling for age and education.

Results

Figure 3 shows data for no-shift and no-shift responses words per utterance (A) , verbs per utterance (B), retracings and repetitions per utterance (C), and filled pauses per syllable (D) for TBI and NBi groups. When the topic shifted, participants' responses had fewer verbs per utterance ($\beta = -0.30$, $p = 0.003$) and words per utterance ($\beta = -0.16$, $p = 0$) relative to when there were no shifts as seen in Figure 3A and 3B. In Figure 3C, it is shown that there were fewer rephrasings and repetitions for responses to new topics versus the same topic ($\beta = -0.39$, $p= 0.0003$). Despite being shorter and less syntactically complex, responses contained a higher frequency of filled pauses ($\beta = 0.25$, $p = 0.00006$) (Figure 3D), a well-established marker of planning difficulty (Arnold, Kam & Tanenhaus, 2007)**.** Like Experiment 1, there were no statistically significant differences in measures of semantic complexity. There were no differences in these general patterns between the healthy and TBI groups. For each significant measure, lower scores were associated with greater severity of injury (determined by duration of loss of consciousness) for the TBI group; however, there were no interactions found between TBI severity and responses to topic shifts.

Figure 3. Differences between NBI and TBI individuals for (a) Total output as shown through words per utterance (b) Syntactic complexity as shown through verbs per utterance (c) Monitoring and revision as shown through rephrasing and repetitions per syllable (d) Planning difficulty as shown through filled pauses per syllable * indicates $p \leq .05$. Error bars indicate 95% confidence intervals.



Discussion for Experiment 2

In order to inform hypotheses about microlinguistic costs of topic-shifting in conversation, Experiment 2 aimed to address the current gap in knowledge concerning how the quality of language output for multiple linguistic levels differs within a given topic and following

a topic-shift. We did this by examining productivity, syntactic complexity, semantic complexity, and fluency in unstructured conversations between moderate to severe TBI patients and experimenters. The first experiment indicated that manipulating topic status does not impact semantic content efficiency and complexity; however, issues from the experimental design and the lack of diverse measures limited the scope of conclusions that could be made of linguistic impacts of topic-shifts. Unlike the first experiment, the results from naturalistic discourse in Experiment 2 demonstrate that there is an effect of topic status on responses, particularly, the total output, verbs per utterance, repetition and rephrasing per utterance, and filled pauses per syllable.

Most current research, treatment, and assessment are based on how well individuals with TBI can generate and maintain topics (Coelho, Liles, Duffy, & Clarkson,1993; Turkstra, Coelho, & Ylvisaker, 2005). However, conversation requires sufficient comprehension and response production on the ends of both the speaker and the listener. In Experiment 2, it was found that responses to topic shifts were shorter, less syntactically complex and elicited less monitoring. Although these simple responses did not require much online revision, they were still harder to plan, as shown by the increase in filled pauses. This suggests that linguistic systems related to general planning and syntactic planning are sensitive to encountering a topic shift. Additionally, these results resemble patterns of costs from non-linguistic set-shifting tasks (Monsell, 2003).

Nonetheless, there were no differences between the TBI and NBI groups for responses to topic shifts. In view of the known difficulties maintaining topics in this sample, the lack of differences in responses between groups may suggest that discourse structure comprehension and production arise from different mechanisms (Coehlo, 2002). It could be that only macro linguistic indicators of discourse comprehension are differentially impacted by topic structure in

TBI, but it is also possible that differences in micro linguistic features would have been difficult to detect regardless because the variability of linguistic functioning in the TBI group as shown by higher TBI severity resulting in lower scores for each measure.

Additionally, it could be that the topic structure is different for individuals with TBI because of problems tracking topic shifts in real time. Future work could use eye-tracking to identify whether TBI patients can detect topic shifts effectively as they unfold in conversation. This would also explain issues producing on-topic responses in this population or perseveration on previous topics. If TBI patients have trouble knowing when the topic is switching, then if and when set-shifting mechanisms are involved in conversation may differ from healthy adults, thus finding differences in responses between groups difficult.

Although examining naturalistic conversation may show the practical effects of switching topics, a more controlled experiment is needed to determine if these topic-shift costs are due to the same mechanisms that produce costs of shifting in non-linguistic contexts (*i.e.* set-shifting). This may include a behavioral study similar to Experiment 1, but examining the significant measures from Experiment 2. Time-sensitive measures like EEG and pupillometry may also be useful to determine more fine-grained differences. For example, although there may be no behavioral effects, pupillometry could reveal neurophysiological indices of increased cognitive effort when encountering topic shifts via pupil dilation differences between conditions for NBI and TBI groups. Meaning, that TBI patients may have to work harder to reach similar levels of performance.

Conclusion

This set of experiments aimed to advance the understanding of specific mechanistic accounts of non-linguistic processes involved in conversational discourse. Here, I tested how

discourse topic status impacts various microlinguistic features of responses in naturalistic conversation to examine the effect on language production. Additionally, I sought to determine whether differences in responses following topic shifts are from the need to engage cognitive mechanisms related to set-shifting by manipulating topic shifts during a semi-structured conversational exchange. Experiment 1 showed that there were no behavioral signatures of set-shifting in terms of how quickly participants produced responses and the semantic complexity of responses. However, there were concerns about how much of this effect can be attributed to considerations of the experimental design. To address this, Experiment 2 used an exploratory approach to inform future hypotheses of the actual linguistic levels impacted by topic shifts in naturalistic conversation. Through Experiment 2, it was found that topic shifts elicit shift costs in syntactic complexity and markers of planning efficiency in both healthy adults and individuals with TBI, but the degree of shift costs was not different between these groups.

Views of mechanistic explanations for shift costs in non-linguistic set-shifting paradigms posit that shift costs arise in situations where the task switches due to the activation of task-relevant information and suppression of task-irrelevant information. Likewise, the Structure-Building Framework proposes that discourse structure is built by mapping information onto existing structures and that building new structures requires the relative activation and deactivation of memory nodes. Gernsbacher (1990) suggests that these costs are due to the need to engage in non-linguistic cognitive processes. Traditional correlational methods have started to uncover this relationship between adherence and comprehension of discourse structure and non-linguistic cognitive processes; however, the specific processes that contribute to particular aspects of discourse are still unknown (Hill, 2018; Lê, Coelho, Mozeiko, Krueger, & Grafman, 2012). The purpose of the current set of studies was to draw the relationship between cognitive

mechanisms related to set-shifting and comprehending conversational discourse structure. Much like previous work in both non-linguistic and linguistic shifting, the results from Experiment 2 display shift costs that are a result of the changing topic structure. Originally, we predicted in Experiments 1 and 2 that the semantic content contained within responses would be impacted by topic shifts due to some accounts of topic being tied to propositions; however, these studies demonstrated otherwise. The lack of differences in propositional content between responses to shifts and no-shift utterances suggests that the understanding of topic is more than the ability to build mental representations from important semantic information (i.e. propositions). Somewhat unexpectedly, production systems related to syntax were impacted by topic-shifts. Thus, it seems that the general increased difficulty from comprehending change in discourse structure resulted in downstream effects in the ability to generate words and complex syntax rather than difficulty forming conceptual representations/activating relevant semantic information related to the topic.

Clinical Applications

TBI pathology generally involves diffuse damage that impedes the effective communication between neural networks. These disruptions often lead to less efficient transmission of information across domains including issues in communication that are a direct result of issues with higher-level cognitive functions. However, the extent to which these cognitive systems are involved in specific features of communication is unknown. This could be one reason why speech therapy techniques for cognitive-communication-related abilities, like conversation, are generally not as effective as treatment methods that address simple linguistic targets that don't require the engagement of higher-level cognitive mechanisms. Developing this relationship between set-shifting and topic-shifting problems in TBI could allow SLPs to better

understand why certain linguistic and discourse abilities are more difficult for certain TBI patients who have trouble with similar non-linguistic tasks. Furthermore, the knowledge of set-shifting deficits and their impact on topic-shifting in TBI patients could inform the development of targeted interventions and treatment strategies to improve discourse skills. For instance, treatment techniques that facilitate specific processes during functional conversation training (e.g. SLP intentionally shifting topics and prompting for more advanced structures during conversation training).

Findings indicating the involvement of set-shifting in conversational discourse could not only be useful for the development of treatments for adults with TBI but also in designing interventions for children or young adults in educational settings. The TBI prevalence among children 0-17 years old in the United States is estimated to be about 2.5% of the population (~1.8 million). Speech and language problems are reported to be one of the most common long-term adverse effects (19%) along with issues with attention (20%); however, issues with other cognitive functions like working memory and set-shifting are also well-documented (Haarbauer-Krupa et al., 2018; Taylor et al., 2008). The ability to rapidly track and produce responses to changing topics is a crucial skill for academic success. For example, engaging in a debate in Social Studies class or answering questions about a recent presentation in English. This also extends to social aspects, like engaging in conversation to connect with peers. Therefore, working on the ability to develop appropriate responses to shifting topics that contain more advanced syntactic structures during conversational training could be beneficial in progressing conversational discourse skills that are relevant to the younger TBI population in schools.

Additionally, similar methods of examining signatures of particular cognitive processes in aspects of discourse may be crucial for creating treatment methods for the school-age

population. For instance, working memory and the ability to comprehend narrative discourse. Understanding and analyzing long passages with many themes or storylines is a skill needed for most school subjects. Lê, Coelho, & Fein (2023) demonstrated that working memory abilities significantly predicted story re-telling performance among individuals with TBI. However, their methods included a correlational approach using adult participants. Future work in this domain could include using a similar methodological approach as this set of studies to examine if there are hallmark characteristics of working memory differences during the comprehension of narrative discourse in school-aged TBI patients.

Methodological Considerations

There are some caveats when considering the validity and generalizability of these findings for special populations such as TBI patients. In the first experiment, we looked for behavioral effects of set-shifting in healthy adults. While these results may be able to suggest a relationship between set-shifting and topic-shifting in a laboratory setting, there should be some hesitation to make particular conclusions regarding impacts for populations with conversational difficulties or set-shifting difficulties. TBI patients, unlike other types of populations with communication disorders, lack a straightforward behavioral and linguistic presentation, despite evidence for commonly shared cognitive-communication deficits. The corpus sample reduced some of these concerns as TBI patients had similar general linguistic profiles and the results factored in particular confounds like age and education. However, although analyzing unstructured conversations is an ecologically valid first step to determining the impacts of topic-shifting on responses, the lack of controlled manipulation of topic status limits any conclusions about the direct cause-and-effect relationship between variables. Systematically

manipulating the appearance of topic shifts in the conversation (possibly using a similar semi-structured exchange as Experiment 1) and measuring effects of total output, syntactic complexity, retracings and repetitions, and filled pauses for responses among TBI patients with known conversational difficulty would allow results to be more suggestive of applied outcomes.

Furthermore, the heterogeneity within the sample, particularly the range of severity of injury, may have impacted the results in Experiment 2 as more severe injury was associated with simpler responses for both no-shift and shift conditions, but not shift costs. It could be that, in severe TBI cases, syntactic and general response planning is already so difficult that it overpowers any effects of shifting. Despite these general trends in severity and response, it also should be noted that the only component of TBI severity available in the corpus data was LOC. Currently, assessment of the severity of injury also includes other relevant predictors of long-term cognitive prognosis such as the Glasgow Coma Scale (GCS) which measures the level of consciousness after a TBI, and Post-Traumatic Amnesia (PTA), which measures the duration of time an individual is unable to access past memories or form new memories. Assessment tools that use consciousness metrics like LOC and GCS alone are reported to be much less predictive of cognitive outcomes (Tenovuo et al., 2021). In the future, additional assessments like the PTA should be used to be able to look at the interactions of severity and the ability to process and produce responses to topic shifts in conversational discourse.

Future Research Directions

Next steps for research in the TBI population could involve exploring the interaction between the type of injury and set-shifting/topic-related conversational discourse difficulties. Forceful jostling of the brain inside the skull can result in the microscopic shearing of axons

throughout the brain referred to as Diffuse Axonal Injury (DAI). The coordination of connections between neural networks is possible through white matter tracts consisting of bundles of myelinated axons that transmit signals between different parts of the brain. When these white matter tracts are disorganized or damaged due to DAI, the communication between networks becomes disrupted or slowed. As previously mentioned, network hyperconnectivity from physiological and mechanical changes in white matter from TBI is associated with chronic cognitive dysfunction. This is supported by studies that use Diffusion Tensor Imaging (DTI) methods to measure the integrity of white matter tracts using information about the diffusion rate and directionality of water molecules along axons. DTI parameters include diffusivity and fractional anisotropy, which is a measure of the summative direction of diffusion and provides information about the degree of fiber organization (Ranzenberger & Snyder, 2022). DTI studies on the TBI population have shown a strong correlation between cognitive measures and these DTI parameters, suggesting that this specific pathology serves the basis for cognitive dysfunction (Dinkel et al., 2014; Wang & Li, 2016). In a study by Kinnunen et al. (2011), they used DTI to determine if patterns in white matter disruption predict specific types of cognitive deficits. Out of a number of cognitive tests, they found a significant relationship specifically between decreased performance in set-shifting as shown through the Trail Making Test (TMT) alternating switch-cost index and increased radial diffusivity: diffusivity perpendicular to the axon. Future work could use DTI to examine if particular diffusivity patterns are associated with difficulty in topic-shifting or generating topics/on-topic responses. If increased radial diffusivity in TBI patients is related to conversational discourse issues (like it is to TMT performance), it could reveal a connection between the underlying neural pathology of these non-linguistic and non-linguistic abilities.

In addition, future studies could explore the other aspects of conversational discourse that may engage cognitive mechanisms related to set-shifting. This may include looking at whether TBI patients and healthy adults experience shift costs during speaker switches during conversation. Additionally, examining if there are behavioral and neural markers hallmarks to uncover if set-shifting contributes to the ability to process speaker-switches. In conversation, there can be many different interlocutors. Everyday conversational partners may differ in speech rate, acoustic quality, accent, and experiences in ways that may affect the flow of the conversation, expectations for topics being discussed, or how a conversational partner responds. These pragmatic factors are important to consider during functional communication, especially given that TBI patients experience greater social isolation post-injury (Salas et al., 2018; Lê, Coelho, & Fiszdon, 2022)..

Furthermore, past work has revealed shifting effects in clinical assessments, particularly verbal fluency tests, in TBI patients. In verbal fluency tasks, participants are asked to produce as many words within a semantic or phonemic category within a designated time period (typically 60 seconds). Kavé, et al. (2011) found that TBI patients showed difficulty in producing related lexical items in a verbal fluency task when it required a switching component. This was shown through the decreased number of switches and number of clusters of words. Given known set-shifting deficits in the TBI population, the authors suggest that these effects are due to executive functioning (EF) problems in individuals with TBI rather than linguistic. Conflicting views argue that these differences in performance are due to language processing demands primarily. In a factor-analytic study by Whiteside et al. (2016), they found that when administering a variety of language and EF tasks, verbal fluency only significantly loaded on the language factor and not EF. Despite this, they assert that this does not indicate EF is not

involved, but rather linguistic processing is the main component impacting verbal fluency performance. A study specifically examining the involvement of a single cognitive process, such as set-shifting, in a verbal fluency task in both healthy adults and TBI patients that share a similar EF profile (*e.g.* reduced performance on set-shifting tasks) would help bridge the gap between these two findings. Additionally, it would further the understanding of certain linguistic situations set-shifting deficits would impact.

Finally, future studies could also explore the relationship between set-shifting and other aspects of discourse. Deictic shift theory (DST) explains how readers become immersed in a story through integrating contextual information centering the narratorial perspective or a character's perspective. A recent study by Li, Dijkstra, & Zwaan (2023) showed that when verbatim memory was unavailable (due to an intervening task) dietic shifts in narrative discourse result in greater ROLs when prompted to produce more complex syntactic forms when asked to repeat what a character said within the story (*i.e.* direct vs. indirect speech). The researchers attribute this to the lack of access to verbatim memory alone. However, like topic-shifting and set-shifting, in order to produce indirect speech to recount the story, mental representations must change as a result of the dietetic shift (e.g. shift: Don says "I went to the bank yesterday" vs. no-shift: his friend Sam says "Don went to the bank yesterday"). Further research could determine if set-shifting is involved in the ability to process dietetic shifts or if TBI patients with set-shifting deficits have difficulty processing dietetic shifts in narrative discourse.

Broader Implications

The overall results contribute to the broader understanding of language processing and cognitive mechanisms involved in discourse production by establishing a relationship between

switching between higher-level discourse structure and particular linguistic costs. Given the increased planning difficulty and shorter, less complex responses to topic shifts in the unstructured conversations in Experiment 2, this work demonstrates that topic-shifting in conversation results in patterns of costs that mirror the types of costs that appear in non-linguistic set-shifting experiments. Knowing that set-shifting is involved in switching topics during conversation could provide greater insight into the persistent conversational impairments secondary to TBI given well-reported set-shifting deficits in this population. Contrary to our original hypothesis that TBI patients would have proportionally greater costs, there were no differences between any significant findings from shift vs. no-shift responses between TBI and NBI groups. Regardless, this work advances the understanding of particular processes that are involved in successful conversational discourse abilities by providing evidence for topic-shift costs. This foundation can help inform future work on whether these topic-shift costs arise from the engagement of set-shifting mechanisms.

Appendix

1. Precision and Accuracy Reliability

   rely +c +dm1 filnameA.cha filenameB.cha +t%spa -t*

2. Cohen's Kappa

   rely +c +d2 filnameA.cha filenameB.cha +t%spa -t*

3. Limiting Files
   a. Limit by PINEW: COMBO +s (%spa:^*^$PINEW*) +t%spa +f +d filename.cha
   b. Limit by PISAME: COMBO +s (%spa:^*^$PISAME*) +t%spa +f +d filename.cha

4. FluCalc

flucalc filename.cha +t*PAR

5. DSS

   dss +b*PAR +le *filename.cha

6. SUGAR

   Sugar filename.cha +t*PAR

7. R formula

   a. Experiment 1

      i. ROL: t.test(data_L_wfp$Duration ~ data_L_wfp$Switch == "1").

      ii. Idea Density: t.test(data_IdeaDensity$Density ~ data_IdeaDensity$Switch == "1")

      iii. Prepositions per second: t.test(data_IdeaDensity$Prop_div_ROL_nfp ~ data_IdeaDensity$Switch == "1")

   b. Experiment 2

      i. Total Words: glmer(mor_Words ~ Group*New + Age + Education + offset(log(Total_Utts))+ (1|ID), data=data, family="poisson")

      ii. Verbs per Utterance: lmer(Verbs_Utt~LOC_days*New + Age.x + Education + (1|ID), data=data_info)

      iii. Retracings/Repetitions: glmer(RepRetrace ~ Group*New + Age + Education + offset(log(Total_Utts)) + (1|ID), data=data, family="poisson")

      iv. Filled Pauses per Syllables: glmer(X._Pauses ~ Group*New + Age + Education + offset(log(mor_syllables)) + (1|ID), data=data, family="poisson")

Works Cited

Alyssa M. Lanzi, Anna K. Saylor, Davida Fromm, Houjun Liu, Brian MacWhinney, Matthew L. Cohen, DementiaBank: Theoretical Rationale, Protocol, and Illustrative Analyse (2023).American Journal of Speech-Language Pathology 426-438; 32; 2.doi:10.1044/2022_AJSLP-22-00281

Arnold, J. E., Kam, C. L. H., & Tanenhaus, M. K. (2007). If you say thee uh you are describing something hard: The on-line attribution of disfluency during reference comprehension. Journal of Experimental Psychology: Learning, Memory, and Cognition, 33(5), 914–930. https://doi.org/10.1037/0278-7393.33.5.914

Astle, D. E., Jackson, G. M., & Swainson, R. (2006). Dissociating neural indices of dynamic cognitive control in advance task-set preparation: an ERP study of task switching. Brain research, 1125(1), 94–103. https://doi.org/10.1016/j.brainres.2006.09.092

Badre D. (2008). Cognitive control, hierarchy, and the rostro-caudal organization of the frontal lobes. Trends in cognitive sciences, 12(5), 193–200. https://doi.org/10.1016/j.tics.2008.02.004

Barlow, S. E., Medrano, P., Seichepine, D. R. & Ross, R. S. Investigation of the changes in oscillatory power during task switching after mild traumatic brain injury. Eur. J. Neurosci. 48, 3498–3513 (2018).

Bayley, Mark Theodore MD, FRCPC; Janzen, Shannon MSc; Harnett, Amber MSc, BSc, BScN; Teasell, Robert MD, FRCPC; Patsakos, Eleni MSc; Marshall, Shawn MD, MSc, FRCPC; Bragge, Peter PhD; Velikonja, Diana PhD, MScCP; Kua, Ailene MSc, PMP; Douglas, Jacinta PhD, MSc(Psych); Togher, Leanne PhD, BAppSc(Speech Path); Ponsford, Jennie PhD, AO, MA(Clinical Neuropsychology); McIntyre, Amanda RN. INCOG 2.0

Guidelines for Cognitive Rehabilitation Following Traumatic Brain Injury: Methods, Overview, and Principles. Journal of Head Trauma Rehabilitation 38(1):p 7-23, January/February 2023. | DOI: 10.1097/HTR.0000000000000838

Brown, C., Snodgrass, T., Kemper, S. J., Herman, R., & Covington, M. A. (2008). Automatic measurement of propositional idea density from part-of-speech tagging. Behavior research methods, 40(2), 540–545. https://doi.org/10.3758/brm.40.2.540

Carlson, L. (2012). Dialogue games: An approach to discourse analysis (Vol. 17). Springer Science & Business Media. https://doi.org/10.1007/978-94-015-3963-0_9

Coelho C. A. (2007). Management of discourse deficits following traumatic brain injury: progress, caveats, and needs. Seminars in speech and language, 28(2), 122–135. https://doi.org/10.1055/s-2007-970570

Coelho, C. A., Youse, K. M., & Le, K. N. (2002). Conversational discourse in closed-head-injured and non-brain-injured adults. Aphasiology, 16(4–6), 659–672. https://doi.org/10.1080/02687030244000275

Coelho, C. Management of Discourse Deficits following Traumatic Brain Injury: Progress, Caveats, and Needs. Semin. Speech Lang. 28, 122–135 (2007).

Economics, A. (2009). The economic cost of spinal cord injury and traumatic brain injury in Australia. Report by Access Economics for the Victorian Neurotrauma Initiative. Canberra: Access Economics, 31.

Evans, L. H., Herron, J. E., & Wilding, E. L. (2015). Direct Real-Time Neural Evidence for Task-Set Inertia. Psychological Science, 26(3), 284-290. https://doi.org/10.1177/0956797614561799

Frings, C., Hommel, B., Koch, I., Rothermund, K., Dignath, D., Giesen, C., Kiesel, A., Kunde, W., Mayr, S., Moeller, B., Möller, M., Pfister, R., & Philipp, A. (2020). Binding and Retrieval in Action Control (BRAC). Trends in cognitive sciences, 24(5), 375–387. https://doi.org/10.1016/j.tics.2020.02.004

Garbarino, J., Ratner, N. B., & MacWhinney, B. (2020). Use of Computerized Language Analysis to Assess Child Language. Language, speech, and hearing services in schools, 51(2), 504–506. https://doi.org/10.1044/2020_LSHSS-19-00118

Georges A, M Das J. Traumatic Brain Injury. [Updated 2023 Jan 2]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459300/

Gernbacher, M. A. (1985). Surface information loss in comprehension.Cognitive Psychology, 17, 324-363.

Gernsbacher, M. A. (1991). Cognitive processes and mechanisms in language comprehension: The structure building framework. In Psychology of learning and motivation (Vol. 27, pp. 217-263). Academic Presss

Graesser, A. C., & McNamara, D. S. (2011). Computational analyses of multilevel discourse comprehension. Topics in cognitive science, 3(2), 371-398. https://doi.org/10.1111/j.1756-8765.2010.01081.x

Haarbauer-Krupa, J., Lee, A. H., Bitsko, R. H., Zhang, X., & Kresnow-Sedacca, M. J. (2018). Prevalence of Parent-Reported Traumatic Brain Injury in Children and Associated Health Conditions. JAMA pediatrics, 172(11), 1078–1086. https://doi.org/10.1001/jamapediatrics.2018.2740

Hill, E., Claessen, M., Whitworth, A., Boyes, M. & Ward, R. Discourse and cognition in speakers with acquired brain injury (ABI): a systematic review: Discourse and cognition in speakers with ABI: a systematic review. Int. J. Lang. Commun. Disord. 53, 689–717 (2018).

Hobbs, J. (1990). Topic drift. In B. Dorval (Ed.), Conversational organization and its development (pp. 3-22). Norwood, NJ: Ablex Publishing Corporation.

Hobbs, J.R. (1985). On the coherence and structure of discourse.

Hubbard, J., Kikumoto, A. & Mayr, U. EEG Decoding Reveals the Strength and Temporal Dynamics of Goal-Relevant Representations. Sci Rep 9, 9051 (2019). https://doi.org/10.1038/s41598-019-45333-6

J. Dinkel, A. Drier, O. Khalilzadeh, V. Perlbarg, V. Czernecki, R. Gupta, F. Gomas, P. Sanchez, D. Dormont, D. Galanaud, R.D. Stevens, L. Puybasset, for NICER (Neuro Imaging for Coma Emergence and Recovery) ConsortiumAmerican Journal of Neuroradiology Jan 2014, 35 (1) 23-29; DOI: 10.3174/ajnr.A3616

Kavé, G., Heled, E., Vakil, E., & Agranov, E. (2011). Which verbal fluency measure is most useful in demonstrating executive deficits after traumatic brain injury?. Journal of clinical and experimental neuropsychology, 33(3), 358–365. https://doi.org/10.1080/13803395.2010.518703

Khan, S. M., & Lespérance, Y. (n.d.). Prioritized Goals and Subgoals in a Logical Account of Goal Change-A Preliminary Report.

Kiesel, A., Steinhauser, M., Wendt, M., Falkenstein, M., Jost, K., Philipp, A. M., & Koch, I. (2010). Control and interference in task switching--a review. Psychological bulletin, 136(5), 849–874. https://doi.org/10.1037/a0019842

Kinnunen, K. M., Greenwood, R., Powell, J. H., Leech, R., Hawkins, P. C., Bonnelle, V., Patel, M. C., Counsell, S. J., & Sharp, D. J. (2011). White matter damage and cognitive impairment after traumatic brain injury. Brain : a journal of neurology, 134(Pt 2), 449–463. https://doi.org/10.1093/brain/awq347

Lange, F., Seer, C., & Kopp, B. (2017). Cognitive flexibility in neurological disorders: Cognitive components and event-related potentials. Neuroscience & Biobehavioral Reviews, 83, 496–507. https://doi.org/10.1016/J.NEUBIOREV.2017.09.011

Lê, K., Coelho, C., & Feinn, R. (2023). Contribution of Working Memory and Inferencing to Narrative Discourse Comprehension and Production in Traumatic Brain Injury. Journal of speech, language, and hearing research : JSLHR, 66(7), 2346–2361. https://doi.org/10.1044/2023_JSLHR-22-00632

Lê, K., Coelho, C. & Fiszdon, J. Systematic Review of Discourse and Social Communication Interventions in Traumatic Brain Injury. Am. J. Speech Lang. Pathol. 31, 991–1022 (2022).

Lê, K., Coelho, C., & Fiszdon, J. (2022). Systematic Review of Discourse and Social Communication Interventions in Traumatic Brain Injury. American journal of speech-language pathology, 31(2), 991–1022. https://doi.org/10.1044/2021_AJSLP-21-00088

Lê, K., Coelho, C., Mozeiko, J., Krueger, F., & Grafman, J. (2012). Predicting Story Goodness Performance From Cognitive Measures Following Traumatic Brain Injury. American Journal of Speech-Language Pathology, 21(2). https://doi.org/10.1044/1058-0360(2012/11-0114)

Lezak, M. D. (1995). Neuropsychological assessment (3rd ed.). Oxford University Press.

Li, J., Dijkstra, K., & Zwaan, R. A. (2023). Deictic shift in the production of direct and indirect speech. Language and Cognition, 1–15. doi:10.1017/langcog.2023.48

Logan, G. D., & Bundesen, C. (2003). Clever homunculus: Is there an endogenous act of control in the explicit task-cuing procedure?. Journal of Experimental Psychology: Human Perception and Performance, 29(3), 575.

MacDonald S. (2017). Introducing the model of cognitive-communication competence: A model to guide evidence-based communication interventions after brain injury. Brain injury, 31(13-14), 1760–1780. https://doi.org/10.1080/02699052.2017.1379613

MacDonald S. (2021). The Cognitive-Communication Checklist for Acquired Brain Injury: A Means of Identifying, Recording, and Tracking Communication Impairments. American journal of speech-language pathology, 30(3), 1074–1089. https://doi.org/10.1044/2021_AJSLP-20-00155

MacWhinney, B. (2000). The Childes Project: Tools for Analyzing Talk, Volume I: Transcription format and Programs (3rd ed.). Psychology Press. https://doi.org/10.4324/9781315805672

MAYNARD, D. (1980). Placement of topic changes in conversation. Semiotica, 30(3-4), 263-290. https://doi.org/10.1515/semi.1980.30.3-4.263

Mayr, U. (2006). What matters in the cued task-switching paradigm: Tasks or cues? Psychonomic Bulletin & Review, 13(5), 794–799. https://doi.org/10.3758/BF03193999

Mayr, U., & Keele, S. W. (2000). Changing internal constraints on action: The role of backward inhibition. Journal of Experimental Psychology: General, 129(1), 4–26. https://doi.org/10.1037/0096-3445.129.1.4

McHugh ML. Interrater reliability: the kappa statistic. Biochem Med (Zagreb). 2012;22(3):276-82. PMID: 23092060; PMCID: PMC3900052.

McKewen, M., Cooper, P. S., Wong, A. S. W., Michie, P. T., Sauseng, P., & Karayanidis, F. (2020). Task-switching costs have distinct phase-locked and nonphase-locked EEG power effects. Psychophysiology, 57(5). https://doi.org/10.1111/psyp.13533

Monsell S. (2003). Task switching. Trends in cognitive sciences, 7(3), 134–140. https://doi.org/10.1016/s1364-6613(03)00028-7

Monsell S. (2003). Task switching. Trends in cognitive sciences, 7(3), 134–140. https://doi.org/10.1016/s1364-6613(03)00028-7

Pavelko, S. L., & Owens, R. E., Jr (2017). Sampling Utterances and Grammatical Analysis Revised (SUGAR): New Normative Values for Language Sample Analysis Measures. Language, speech, and hearing services in schools, 48(3), 197–215. https://doi.org/10.1044/2017_LSHSS-17-0022

Perlstein, W. M., Larson, M. J., Dotson, V. M. & Kelly, K. G. Temporal dissociation of components of cognitive control dysfunction in severe TBI: ERPs and the cued-Stroop task. Neuropsychologia 44, 260–274 (2006).

Qiao, L., Zhang, L., Chen, A., & Egner, T. (2017). Dynamic Trial-by-Trial Recoding of Task-Set Representations in the Frontoparietal Cortex Mediates Behavioral Flexibility. The Journal of neuroscience : the official journal of the Society for Neuroscience, 37(45), 11037–11050. https://doi.org/10.1523/JNEUROSCI.0935-17.2017

Ravizza, S. M., & Carter, C. S. (2008). Shifting set about task switching: behavioral and neural evidence for distinct forms of cognitive flexibility. Neuropsychologia, 46(12), 2924–2935. https://doi.org/10.1016/j.neuropsychologia.2008.06.006

Ribas-Fernandes, J. J., Solway, A., Diuk, C., McGuire, J. T., Barto, A. G., Niv, Y., & Botvinick, M. M. (2011). A neural signature of hierarchical reinforcement learning. Neuron, 71(2), 370–379. https://doi.org/10.1016/j.neuron.2011.05.042

Riester, A. (2019). Constructing QUD trees. In Questions in discourse (pp. 164-193). Brill. https://doi.org/10.1163/9789004378322_007

Roberts, C. (1996). Information structure in discourse: towards an integrated formal theory of pragmatics.'Ms. The Ohio State University.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictible switch between simple cognitive tasks. Journal of Experimental Psychology: General, 124(2), 207–231. https://doi.org/10.1037/0096-3445.124.2.207

Sacks, H., Schegloff, E. A., & Jefferson, G. (1974). A Simplest Systematics for the Organization of Turn-Taking for Conversation. Language, 50(4), 696–735. https://doi.org/10.2307/412243

Salas, C. E., Casassus, M., Rowlands, L., Pimm, S., & Flanagan, D. A. J. (2018). "Relating through sameness": a qualitative study of friendship and social isolation in chronic traumatic brain injury. Neuropsychological rehabilitation, 28(7), 1161–1178. https://doi.org/10.1080/09602011.2016.1247730

Schneider, D. W., & Logan, G. D. (2006). Priming cue encoding by manipulating transition frequency in explicitly cued task switching. Psychonomic bulletin & review, 13(1), 145–151. https://doi.org/10.3758/bf03193826

Sharp, D., Scott, G. & Leech, R. Network dysfunction after traumatic brain injury. Nat Rev Neurol 10, 156–166 (2014). https://doi.org/10.1038/nrneurol.2014.15

Sheila MacDonald & Catherine Wiseman-Hakes (2010) Knowledge translation in ABI rehabilitation: A model for consolidating and applying the evidence for cognitive-communication interventions, Brain Injury, 24:3, 486-508, DOI: 10.3109/02699050903518118

Shorland, J., Douglas, J. and O'Halloran, R. (2020), Cognitive-communication difficulties following traumatic brain injury sustained in older adulthood: a scoping review. International Journal of Language & Communication Disorders, 55: 821-836. https://doi.org/10.1111/1460-6984.12560

Sohn, M.-H., & Anderson, J. R. (2001). Task preparation and task repetition: Two-component model of task switching. Journal of Experimental Psychology: General, 130(4), 764–778. https://doi.org/10.1037/0096-3445.130.4.764

Stivers, T., Enfield, N. J., Brown, P., Englert, C., Hayashi, M., Heinemann, T., Hoymann, G., Rossano, F., de Ruiter, J. P., Yoon, K. E., & Levinson, S. C. (2009). Universals and cultural variation in turn-taking in conversation. Proceedings of the National Academy of Sciences of the United States of America, 106(26), 10587–10592.

Taboada, M., & Wiesemann, L. (2010). Subjects and topics in conversation. Journal of Pragmatics, 42(7), 1816-1828. https://doi.org/10.1016/j.pragma.2009.04.009

Taylor, H. G., Swartwout, M. D., Yeates, K. O., Walz, N. C., Stancin, T., & Wade, S. L. (2008). Traumatic brain injury in young children: postacute effects on cognitive and school readiness skills. Journal of the International Neuropsychological Society : JINS, 14(5), 734–745. https://doi.org/10.1017/S1355617708081150

Tenovuo, O., Diaz-Arrastia, R., Goldstein, L. E., Sharp, D. J., van der Naalt, J., & Zasler, N. D. (2021). Assessing the Severity of Traumatic Brain Injury-Time for a Change?. Journal of clinical medicine, 10(1), 148. https://doi.org/10.3390/jcm10010148

Uddén, J., de Jesus Dias Martins, M., Zuidema, W., & Tecumseh Fitch, W. (2020). Hierarchical Structure in Sequence Processing: How to Measure It and Determine Its Neural Implementation. Topics in Cognitive Science, 12(3), 910–924. https://doi.org/10.1111/tops.12442

Understanding traumatic brain injury: current research and future directions. (Oxford University Press, 2014).

Wang, M. L., & Li, W. B. (2016). Cognitive impairment after traumatic brain injury: The role of MRI and possible pathological basis. Journal of the neurological sciences, 370, 244–250. https://doi.org/10.1016/j.jns.2016.09.049

Whiteside, D. M., Kealey, T., Semla, M., Luu, H., Rice, L., Basso, M. R., & Roper, B. (2016). Verbal Fluency: Language or Executive Function Measure?. Applied neuropsychology. Adult, 23(1), 29–34. https://doi.org/10.1080/23279095.2015.1004574

Wylie, G., & Allport, A. (2000). Task switching and the measurement of "switch costs". Psychological research, 63(3-4), 212–233. https://doi.org/10.1007/s004269900003