Does the Thematic Hierarchy hold in people with aphasia and across the lifespan? Evidence from the Event Task.

by

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Aphasia is a neurological disorder that can disrupt language production and comprehension, impairing both written and spoken language (Dresang et al., 2019). This condition is typically brought on by brain damage following a stroke. Research indicates that people with aphasia sometimes rely on event knowledge to compensate for their language impairment (Caramazza & Zurif, 1976). However, we know little about event processing in people with aphasia (PWA), even though event knowledge supports a multitude of crucial cognitive processes, including language comprehension, language production, memory, and perception. One type of event knowledge that has been studied thoroughly in linguistics is the entities, objects, and locations (event roles) that are involved in events. Linguists have developed a hypothesis, known as the Thematic Hierarchy, that some of these event roles are more cognitively salient than others. The research I present here uses evidence from a new assessment that measures event knowledge (the Event Task) to evaluate whether this thematic knowledge is maintained in older adults and people with aphasia, while also examining whether the performance of PWA on the Event Task is aligned with the Thematic Hierarchy. PWA (N = 26) and neurologically healthy adults (N = 182) completed the Event Task, which instructed participants to identify whether a depicted event was plausible or implausible. Analyses showed that the Thematic Hierarchy did not appear to guide the performance of PWA or neurologically healthy adults across the lifespan. However, PWA and neurologically healthy controls alike displayed the same patterns of both accuracy and reaction time performance. In neurologically healthy adults, increased age was correlated with decreased accuracy and increased reaction times. In addition, neurologically healthy adults with 12+ years of education were found to have increased accuracy and decreased reaction times. The current findings could be the foundation for future research regarding aphasia and event knowledge.

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Preface

First and foremost, I would like to express my gratitude to Dr. Michael Walsh Dickey, my mentor and Bachelor of Philosophy advisor. Thank you for the years of guidance, encouragement, and insight. I will never forget the invaluable lessons he taught me and the countless hours he dedicated to my project. Joining the Language and Brain Lab and learning under his guidance truly changed the trajectory of my career, and I cannot express the full extent of my appreciation. In addition, I am so lucky to have studied under Dr. Tessa Warren, my incredible Honors in Psychology advisor. Her mentorship has been imperative in honing my writing skills and finding my voice in the scientific community. Her dedication and expertise have been instrumental in helping me become the researcher I am today.

I am very grateful to Dr. Julie Fiez and Dr. Jamie Reilly, for their enthusiasm and willingness to serve on my thesis committee. I would like to acknowledge the University of Pittsburgh Honors College for providing this wonderful opportunity and supporting my work with resources such as the Brackenridge Fellowship. I am extremely appreciative of Emily Goldberg, for assisting with data compilation efforts and cheering me on since my very first lab presentation over two years ago. Finally, I would like to thank my friends and family, for providing unwavering support and encouragement as I pursued this project.

1.0 Introduction

1.1 Semantic memory and event knowledge

Semantic memory is an individual's long-lasting memory for general knowledge about the world (Dresang et al., 2019). From birth, we begin collecting knowledge about the world. Semantic memory is critical when trying to produce or understand language. For example, when you hear a word or sentence, you consult your knowledge about objects, people, actions, and things to understand the meaning of that sentence. Semantic memory is often impaired in PWA, and an accurate measure of semantic memory impairment is crucial for treatment (Antonucci & Reilly, 2008). Existing picture-based assessments of object-related semantic memory include Pyramids and Palm Trees (PPT) (Howard et al., 1992) and the Camels and Cactus Test (CCT) (Bozeat et al., 2000). There is also a picture-based assessment of action-related semantic memory called the Kissing and Dancing Test (KDT) (Bak & Hodges, 2003). However, there are few tests to measure semantic memory for events in PWA (Dresang et al., 2019).

Events can be defined as collections of people, objects, actions, places, and the context in which they occur (Dresang et al, 2019). Event roles (or thematic roles) are the people, places, and things that play a role in an event. The agent is the initiator of an action (Ünal et al., 2021). The patient is the entity undergoing the effect of some action, often undergoing some change in state (Ünal et al., 2021). The instrument is the tool used to perform an action (Ünal et al., 2021). The location is the place in which something is situated (Saeed et. al, 1996). The goal is the entity towards which something moves, either literally or metaphorically (Ünal et al., 2021). An example of this would be the following sentence: "The boy hit the baseball with his bat on the field." The agent would be “the boy” as he is the one doing the act. The action is hit. The patient is the baseball because it is moved by the action. The instrument is the bat because the boy uses the bat as a tool to hit the ball. The location is the baseball field on which he is playing the game.

Event role knowledge is activated during language processing. Some evidence for this comes from a study in which adult participants were given line drawings of two-participant events—for example, a man throwing a football to a woman—and were asked to describe the events (Griffin & Bock, 2000). Eye-tracking data showed that the participants’ eye movements were guided by event features prior to sentence formulation. Participants gazed at the agent prior to speech, then looked to the patient as they began speaking, and finally returned their gaze to the agent. The results showed that participants “rapidly extract roles of event participants” while describing the line drawing (Griffin & Bock, 2000). Event knowledge provides context that helps individuals understand novel events by providing prototypical events for comparison (McRae & Matsuki, 2009). Language processing is reliant on event knowledge, as it supports verb retrieval and thematic-role processing (Dresang et al., 2019).

1.2 The Thematic Hierarchy

The Thematic Hierarchy is the idea that certain event roles are more prominent than others (Ünal et al., 2021). An event role near the top of the hierarchy would have more prominence, meaning that it should be identified earlier and processed more quickly than a non-prominent event role. Agents are at the top of the hierarchy and are most salient or prominent. Next are Patients, followed by Goals. Instruments are second-to-lowest on the thematic hierarchy. Finally, locations are the least prominent role. Linguistic research indicates that agents are most prominent because they are linguistically encoded as subjects (Baker, 1997; Jackendoff, 1990). Patients are next because they are direct objects of the verb. Goals, instruments, and locations are the least likely to be in these syntactic positions, leading to a lower prominence on the thematic hierarchy. Instruments are rarely selected as verb arguments and even referred to as “secondary roles” (Baker, 1997). This hierarchy naturally predicts that event roles towards the top of the Thematic Hierarchy will be mentioned more frequently or identified more easily than event roles from the bottom of the Thematic Hierarchy.

I will now outline the experimental evidence supporting the Thematic Hierarchy. Agents and patients are expected to be prioritized over other event roles because of their positions towards the top of the Thematic Hierarchy. Consistent with this, Hafri et al (2018) found that information about agents and patients is often extracted even when it is not directly encouraged by a task or while the participant is preoccupied with another task (Hafri et al., 2018). Participants viewed an array of stimuli images depicting a simple interaction between a male and a female and were instructed to answer which character, the male or the female, was on the left or right half of the screen. When presented with subsequent images in which the event role of the target character differed from one trial to the next, the participants displayed an event role switch cost, a delay in reaction time caused by the shift in event role. Hafri et al.’s study found that although task instructions did not explicitly refer to event roles, participants’ reaction times were affected by the event role change, indicating that event role information is spontaneously encoded even when not directly related to the task at hand.

Research suggests that instruments are not prioritized unless the instrument is deemed particularly relevant to the story being told. Studies show that English speaking adults consistently omit instruments in retelling stories involving instrument events (Lockridge & Brennan, 2002).

The instrument is even more likely to be omitted from the retelling if it is a common or typical instrument. Lockridge and Brennan (2002) found that during story retellings, atypical instruments were most often explicitly disclosed to the partner early in the story, whereas an instrument that is inferable from the story was not mentioned as frequently. These findings suggest that although instruments can provide crucial information about an event, they are not attended to with the same focus that an agent or patient would receive, which is consistent with their low role on the Thematic Hierarchy.

Locations are positioned at the bottom of the Thematic Hierarchy. Ferretti et al (2001) used single word priming to investigate how verbs activate event role knowledge (Ferretti et al., 2001). Results showed that verbs primed all event roles except for locations (Ferretti et al., 2001). These findings are consistent with the idea that locations are the least salient of all event roles, resulting in location's place at the bottom of the Thematic Hierarchy.

From a cognitive perspective, the Thematic Hierarchy would predict that entities in more prominent event roles would be remembered better and identified more easily than entities in less prominent roles. This claim is supported by a study by Ünal et al. (2021) that tested young learners of English and Turkish in order to determine whether asymmetries in event role prominence generalize to other languages. The study had two parts: a linguistic description task and a change-blindness task. In the linguistic description task, participants were asked to describe event stimuli images. Event role prioritization was measured by how frequently participants mentioned each event role when describing a stimuli image. For the change-blindness task, four new stimuli images were created from each original stimuli image by changing the color of one event role. In the task, the original stimuli image was displayed, followed by a grey screen. Next, the new stimuli image featuring the color change was shown, followed by another grey screen. The cycle would then repeat. Participants were instructed to respond as soon as they detected the changing object. In this task, event role prioritization was measured by how quickly the participant responded to the changed event role.

Findings suggested that agents were prioritized in both language groups. Patients and goals tended to be similarly prioritized over instruments in both languages as well. The relative salience of event roles was similar across young learners of both English and Turkish (Ünal et al., 2021). This is particularly interesting because even though there is variation in the way these event roles are encoded across the two languages, event roles were prioritized in similar ways, which aligns with the Thematic Hierarchy. My thesis explores the theory that people should be faster and more accurate to detect incongruency when it appears in more prominent roles than in less prominent roles.

1.3 The Event Task

The Event Task is a picture-based assessment of semantic memory. The preliminary version of the assessment was developed in the Language and Brain Lab at the University of Pittsburgh. The task's goal is to measure how functional or impaired an individual's ability to access their semantic memory for events is. In the task, the participant is given photographs of events that are either plausible or implausible. Plausible events would be those that would commonly occur in everyday life, such as a person doing work at a desk or boxing in a gym. Implausible events are impossible or unlikely, and do not match our everyday experience or our world knowledge based in semantic memory. Images like a man playing the violin underwater and a woman with her head in a bag are clear examples of implausible events taken directly from the

Event stimuli. In each implausible image, at least one event role is incongruent with the event depicted. Participants were shown one image at a time and were asked to indicate if this scene was something that may normally happen.

A study conducted by Dresang et al. (2019) assessed the preliminary validity of the Event Task. The study's first aim was to characterize typical performance and distinguish stimulus characteristics of the Event Task. To that end, it gathered data from 90 neurologically healthy adults across the lifespan and identified both average performance at multiple age-ranges and variation in processing time across the plausible and implausible images (Dresang et al., 2019). The second aim was to establish the Event Task's sensitivity to neurological impairment. Findings concluded that the Event Task was successful in detecting those participants afflicted with aphasia, indicated by distinctions between neurologically healthy age-matched controls and PWA (Dresang et al., 2019). The third and fourth aims were to demonstrate that the Event Task shows preliminary evidence of convergent validity with measures of language processing and assessments of action and object knowledge. Poor Event Task performance was correlated with greater deficits in verb retrieval (specifically, verb production) and thematic-role processing (specifically, producing agent, patient, and other thematic roles in sentences), and Event Task performance was predicted by KDT (action based semantic memory assessment) performance and PPT (object based semantic memory assessment) performance (Dresang et al., 2019). These findings suggest that Event Task performance is indicative of verb retrieval abilities and thematic-role processing abilities, which are crucial for language processing. The current study expands upon the foundational work of Dresang et al. by examining whether the Thematic Hierarchy's predictions regarding the salience of various event roles hold for Dresang et al.'s Event Task data.

1.4 The Current Study

My research investigated performance on the Event Task in relation to the Thematic Hierarchy. My research tested whether there was a correlation between the relative prominence of event roles according to the Thematic Hierarchy (agents > patients > instruments > locations) and accuracy and reaction time for implausible Event Task pictures which contain violations of our expectations about those event roles. For example, the stimulus image of a man playing the violin in the ocean would be a location violation, as the location (the ocean) is not a typical place for that event to occur. I hypothesized that there would be a positive correlation between Thematic Hierarchy position and accuracy, with higher accuracy for more prominent event roles. I hypothesized that there would be a negative correlation between Thematic Hierarchy position and reaction time, with lower (or faster) reaction times for more prominent event roles.

If the event roles identified as incongruent most accurately and quickly were those event roles near the top of the Thematic Hierarchy, that would suggest the Thematic Hierarchy is a good indicator of event role prominence. If the Thematic Hierarchy proves to be a good indicator of which event roles elicit the fastest or most accurate responses in the Event Task, then it might suggest that aphasia treatment could be adjusted to focus on improving comprehension of those event role categories that PWA respond to inaccurately or slowly. If the predicted relationship between the Thematic Hierarchy and Event Task performance is not found, that would suggest that the Thematic Hierarchy does not guide event roles in relation to PWA.

2.0 Methods

2.1 Participants

As reported in Dresang et al. (2019), Event Task data was collected from 208 participants, including 26 PWA and 182 neurologically healthy participants across the lifespan. These healthy participants were divided into groups of 15 in the following age ranges: 20-29, 30-39, 40-49, 50-59, 60-69, 70-79. The healthy control groups allowed for Event Task performance analysis across the lifespan. All healthy participants were required to have no history of language, speech, or neurological impairments. All participants attained a score of >24 on the Mini-Mental State Examination, an assessment of cognitive function (MMSE) (Folstein et al., 1975). All participants were monolingual native English speakers with normal or corrected-to-normal hearing and vision. All participants provided informed consent and received compensation for their participation in the study (Dresang et al., 2019). 4 participants were found to have incomplete Event Task data, resulting in exclusion from the analysis.

2.2 Event Task Stimuli and Procedure

The Event Task is composed of 260 colored images, including 256 experimental images and 4 practice images (Dresang et al., 2019). The photographs depict people engaging in basic actions in a variety of environments. Half of these images portray plausible events, such as a person boxing at a gym, and the other half portray implausible events, such as a man playing the violin underwater. Implausible events are impossible or unlikely, and do not match our everyday experience or our world knowledge based in semantic memory. Implausible event images were characterized as stimuli that “violates so-called ‘world knowledge’ about typical human actions in ecological environments” (Proverbio & Riva, 2009). In each implausible image, at least one event role is incongruent with the event depicted. Incongruent event roles conflict with an individual’s semantic memory for typical events of this type. Participants were shown one image at a time and were asked to indicate if this scene was something that may normally happen by pressing a button on the keyboard—the key labeled “1” indicated that the event “might normally happen” (a plausible event) and the key labeled “5” indicated that the event “might not normally happen” (an implausible event). Participants were instructed to respond as accurately and as quickly as possible (Dresang et al., 2019).

2.3 Data Compilation

I imported the Event Task data from E-Prime to Excel, and then consolidated the data into one Excel file. The final Event Task Dataset included information such as participant code, trial number, correct answer, accuracy, and reaction time. All participant demographic information was manually transferred from printed files into an Excel file, including date of birth, education, Mini-Mental State Examination score, and participant code. Each PWA was matched to a neurologically healthy participant with the same age and years of education. The dataset consisting of PWA and matched healthy participants was used to compare event role accuracy and reaction time between the two groups.

2.4 Event Taxonomy Questionnaire

In order to evaluate which event role may have caused the incongruence in each implausible image, referred to as an event role violation, we used data from an Event Taxonomy Questionnaire. In the questionnaire, 37 volunteer participants were given event role definitions and were asked to indicate which event roles created the incongruency in the 130 implausible stimuli images from the Event Task. For example, in the image of a nail being hammered with a shoe, the implausible event role would be the instrument. 5 practice images were given with explanations as to which event role was violated to ensure comprehension of the instructions. The data consisted of 33 participants' responses, as 4 participants were excluded due to incomplete questionnaires.

The individual Event Taxonomy Questionnaire responses were compiled into one Excel file. The number of ratings for each event role dimension per stimuli image was totaled. The mean number of rated violations for each event role dimension across all incongruent stimuli was calculated. To be considered a canonical event role violation (for any given stimuli image), the number of ratings had to be 2 SD above the mean for that dimension. For example, if a stimuli image's number of agent violation ratings was 2 SD above the mean number of agent violation ratings across all incongruent stimuli, that stimuli image would be classified as having a canonical agent violation. To also be considered an exclusive event role violation, the stimuli image must have canonical ratings for only one event role dimension. The data was then converted into binary data ("1" for an event role violation and "0" for lack thereof) which was imported to the Event Task Dataset. This data indicated which event role was violated per stimuli image per participant trial, allowing thematic hierarchy data analysis to occur.

2.5 Data Analysis

The Event Taxonomy Questionnaire data was summarized via pivot table, presenting the number of canonical and exclusive event role violations in the incongruent stimuli set.

Table 1: Canonical and Exclusive Event Role Violations

	Agent	Patient	Instrument	Location
Canonical Event Role Violations	25	23	18	29
Exclusive Event Role Violations	16	19	13	23

Exclusive event role violations were used to generate the ordered factor Thematic Hierarchy variable. Using exclusive violations ensured that stimuli images each have one clear event role violation, which made it possible to map that violation to a single position on the Thematic Hierarchy. Data analysis was conducted via R using a regression analysis including both linear mixed effects models and generalized linear mixed effects models.

3.0 Results

3.1 PWA and Matched Controls Analyses

An initial generalized linear mixed-effects model compared accuracy at detecting violations of four different event roles across PWA and healthy control participants who were matched to the PWA by age and years of education. All analyses were conducted using only incongruent stimuli. Model glmer(EventAccuracy ~ Group*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) compared accuracy performance among event role violation types across both groups, while accounting for random effects across subjects and items. Agent violations were coded as 1 (i.e., the reference level) due to agent holding the highest position on the Thematic Hierarchy. Because agents are at the top of the Thematic Hierarchy, we expected them to yield the highest accuracy and lowest reaction time. Both groups' average accuracy performance per event role violation type is depicted in Figure 1. Mean accuracy was relatively high for the agent and patient violations, at around 86%, and not much lower for the location violations. Instrument violations had the lowest accuracy. However, none of these differences were reliable (Agent vs. Instrument: Estimate = -0.75798, SE = 0.44675, p value = -0.0898), (Agent vs. Patient: Estimate = 0.01634, SE = 0.40747, p value = 0.9680), and (Agent vs. Location: Estimate = -0.21022, SE = 0.39464, p value = 0.5943). There was no reliable effect of Group (Estimate = 0.24334, SE = 0.34004, p value = 0.4742) and no reliable interaction between Group and patient (Estimate = 0.14145, SE = 0.30828, p value = 0.6463), instrument (Estimate = 0.53204, SE = 0.34735, p value = 0.1256), or location (Estimate = 0.28329, SE = 0.30130, p value = 0.3471).

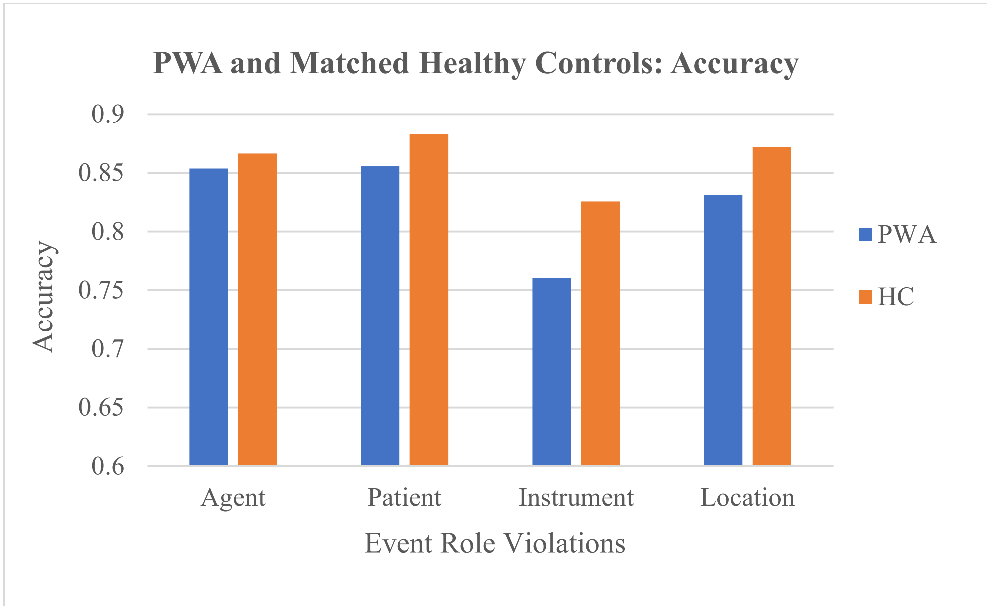

Figure 1: PWA and matched control participants' accuracy performance.

A parallel analysis of reaction time included only trials on which participants answered correctly. We analyzed the time it took for participants to detect event role violations using the following model: lmer(RT ~ Group*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)). Figure 2 displays both groups' average reaction time performance per event role violation type. Patient violations yielded the highest reaction times in both groups. In PWA, patient violation reaction times were about 200 to 300 ms slower than the average for agent, instrument, and location violations, which ranged from about 1950 ms to 2050 ms. In the healthy control group, patient violation reaction times were about 100 to 200 ms slower than the average for agent, instrument, and location violations, which ranged from about 1720 to 1820 ms. However, none of these differences were reliable (Agent vs. patient: Estimate = 126.01, SE = 104.99, t value =1.200), (Agent vs. instrument: Estimate = 29.25, SE = 114.58, t value = 0.255), and (Agent vs. location: Estimate = -172.57, SE = 100.63, t value = -1.715). Group had a reliable effect reaction time (Estimate = -388.502, SE = 158.553, t value = -2.450). No reliable interaction was found between

Group and patient (Estimate = -34.384, SE = 74.984, t value = -0.459), instrument (Estimate = 33.311, SE = 77.879, p value = 0.428), or location (Estimate = -8.582, SE = 69.416, p value = -0.124).

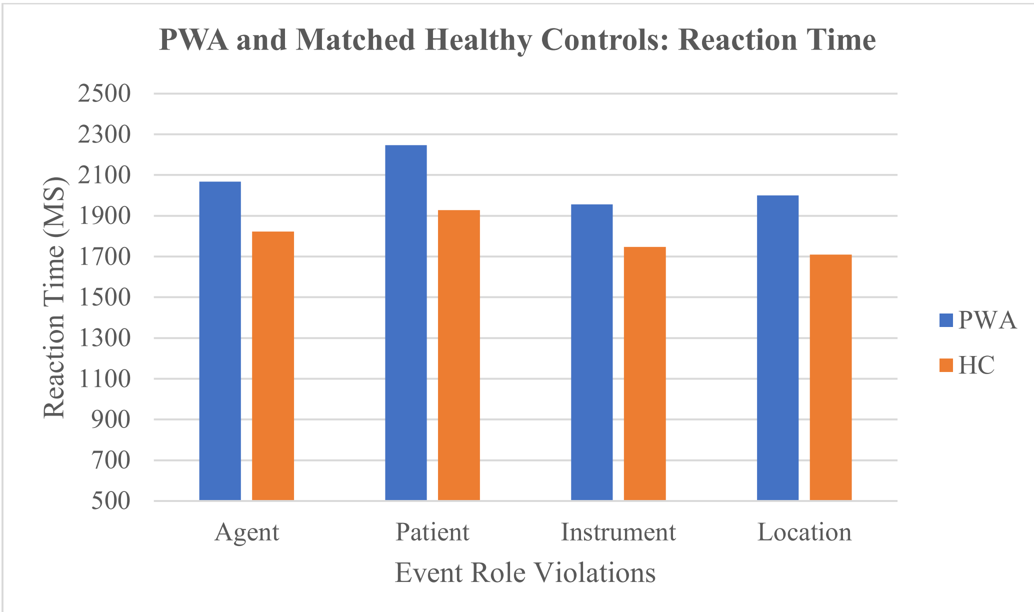

Figure 2: PWA and matched control participants' reaction time performance.

3.2 PWA Analyses

The next set of analyses were identical to the ones reported in the previous section, except that they only included data from PWA. These analyses aim to investigate whether the Thematic Hierarchy guides PWA accuracy and reaction time performance on the Event Task, examining individual PWA performance in more depth than the previous analysis. Model glmer(EventAccuracy ~ ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) compared accuracy performance among event role violation types in the PWA sample. As depicted in Figure 1, mean accuracy was approximately 85% for agent and patient violations with location violations following close behind, averaging 83%. Instrument violations had the lowest accuracy, averaging 76%. None of these differences were reliable (Agent vs Instrument: Estimate = -0.75384, SE = 0.40886, p value = 0.0652), (Agent vs. Patient: Estimate = 0.01364, SE = 0.37801, p value =0.9712), and (Agent vs. Location: Estimate = -0.16820, SE = 0.36538, p value = 0.6453).

In contrast to the mean accuracy across all PWA per event role violation type reported in Figure 1, Figure 3 shows an in-depth description of accuracy performance per individual PWA. As depicted in Figure 3, 19 of 26 PWA displayed the lowest accuracy performance on instrument violations. This unexpected result was identified in the majority of PWA's accuracy performance, which is particularly interesting considering the higher accuracy average of location violations, which are ranked lower on the Thematic Hierarchy than instruments and therefore were expected to display the lowest accuracy performance. One PWA displayed the expected pattern: agent violations being most accurate, followed by patient violations, instrument violations, and, finally, location violations. The six PWA who were furthest from the expected pattern displayed unique accuracy performance patterns which did not align with the expected pattern or common performance across all PWA. For example, participant 218 had the highest accuracy for instrument violations and the lowest accuracy for agent violations, which is far from both the expected pattern and the performance of most PWA in this sample. The PWA that were furthest from the expected pattern exemplify some of the variability seen across PWA accuracy performance.

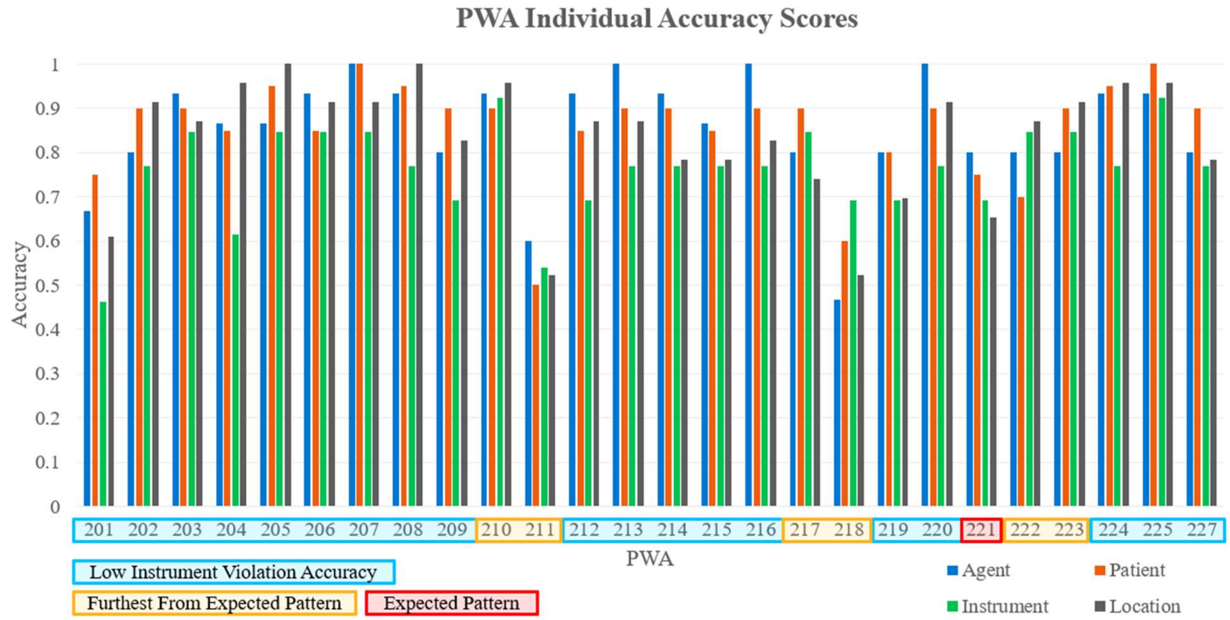

Figure 3: Individual PWA accuracy performance per event role violation type.

Model lmer(RT ~ ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) compared reaction time performance among event role violation type in the PWA sample. Mean reaction time was relatively stable at around 2000 ms across agent, instrument, and location violations. Patient violations had the highest reaction time, averaging 2245 ms. However, none of these differences were reliable (Agent vs. Patient: Estimate = 198.706, SE = 123.046, t value = 1.615), (Agent vs. Instrument: Estimate = -24.131, SE = 133.104, t value = -0.181), and (Agent vs. Location: Estimate = -33.977, SE = 115.503, t value = -0.294).

In contrast to the mean reaction times for PWA per event role violation type provided in Figure 2, Figure 4 provides reaction time performance for individual PWA across all event role violation types. 18 of 26 PWA displayed the slowest reaction time for patient violations. None of the PWA exhibited the expected pattern of reaction time performance. One PWA was identified as being furthest from the expected pattern: participant 222 displayed the highest reaction time for agent violations, followed by instrument, patient, then location violations. This performance pattern did not align with the expected pattern or common performance across all PWA. Although participant 222 exhibits a particularly unique pattern, reaction time variability is seen across all PWA.

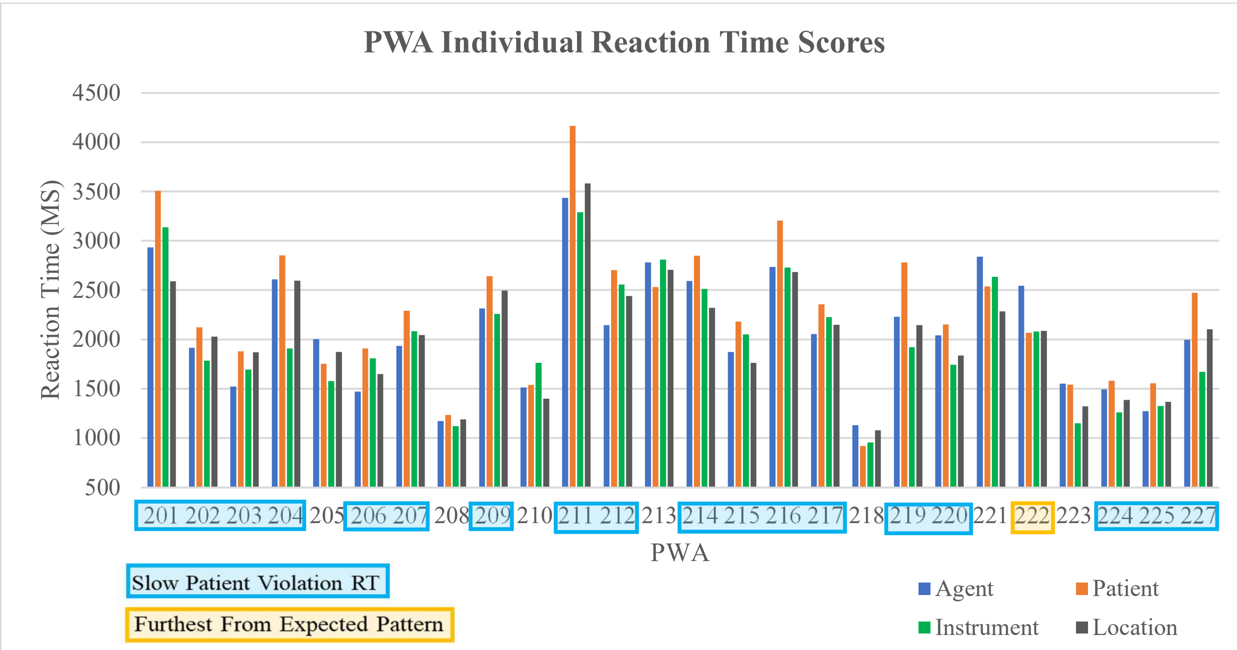

Figure 4: Individual PWA reaction time performance per event role violation type

3.3 Lifespan Analyses

The following analyses were conducted using Event Task data from 170 neurologically healthy adults across the lifespan, utilizing the incongruent Event Task trials to assess accuracy and reaction time in relation to the Thematic Hierarchy. These analyses investigate whether the Thematic Hierarchy guides Event Task performance on neurologically healthy adults across the lifespan. Additionally, these analyses include demographic information including age, MMSE score, and years of education to examine what other factors impact Event Task accuracy and reaction time performance.

3.3.1 Age Analyses

A generalized linear mixed effects model investigated the relationship between accuracy, age, and the Thematic Hierarchy. The Thematic Hierarchy variable was coded with the R function as.integer, meaning that each event role violation type corresponds with an ascending number in accordance with the Thematic Hierarchy rankings. Agent, patient, instrument, and location violations are coded as 1, 2, 3, and 4 respectively. Model glmer(EventAccuracy ~ Age*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) indicated that age has a reliable effect on accuracy (Estimate = -0.015105, SE = 0.007156, p value = 0.0348). Figure 5 provides average accuracy per event role violation type across the lifespan. As age increased, accuracy decreased on all event role violation types. The Thematic Hierarchy did not have a reliable effect on accuracy (Estimate = 0.028055, SE = 0.146167, p value = 0.8478). There was no reliable interaction found between age and Thematic Hierarchy (Estimate = -0.002082, SE = 0.001851, p value = -0.2608).

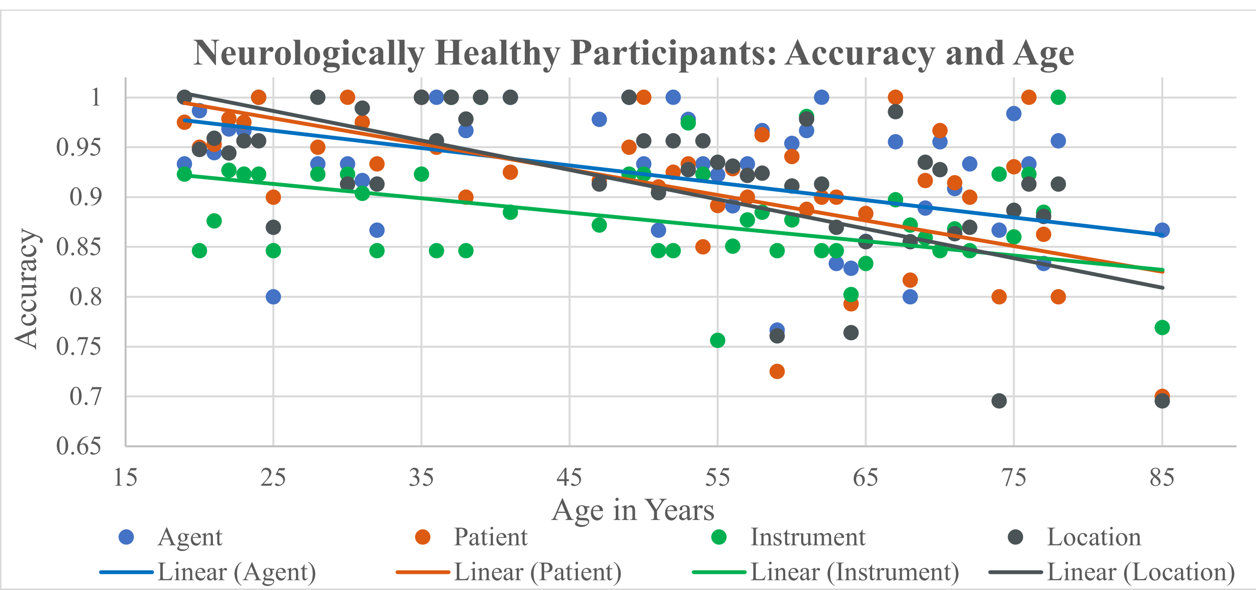

Figure 5: Healthy participants' accuracy performance in relation to age.

A linear mixed effects model assessed age and the Thematic Hierarchy in relation to reaction time. Model lmer((RT ~ Age*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) indicated that age had a reliable effect on reaction time (Estimate = 7.161, SE = 1.932, t value = 3.707). Figure 6 displays average reaction time performance per event role violation type across the lifespan. As age increases, reaction time increases. Thematic Hierarchy did not have a reliable effect on reaction time (Estimate = 29.83, SE = 29.09, t value = 1.026). There was no reliable interaction found between age and Thematic Hierarchy (Estimate = 0.013, SE = 0.2705, t value = 0.048).

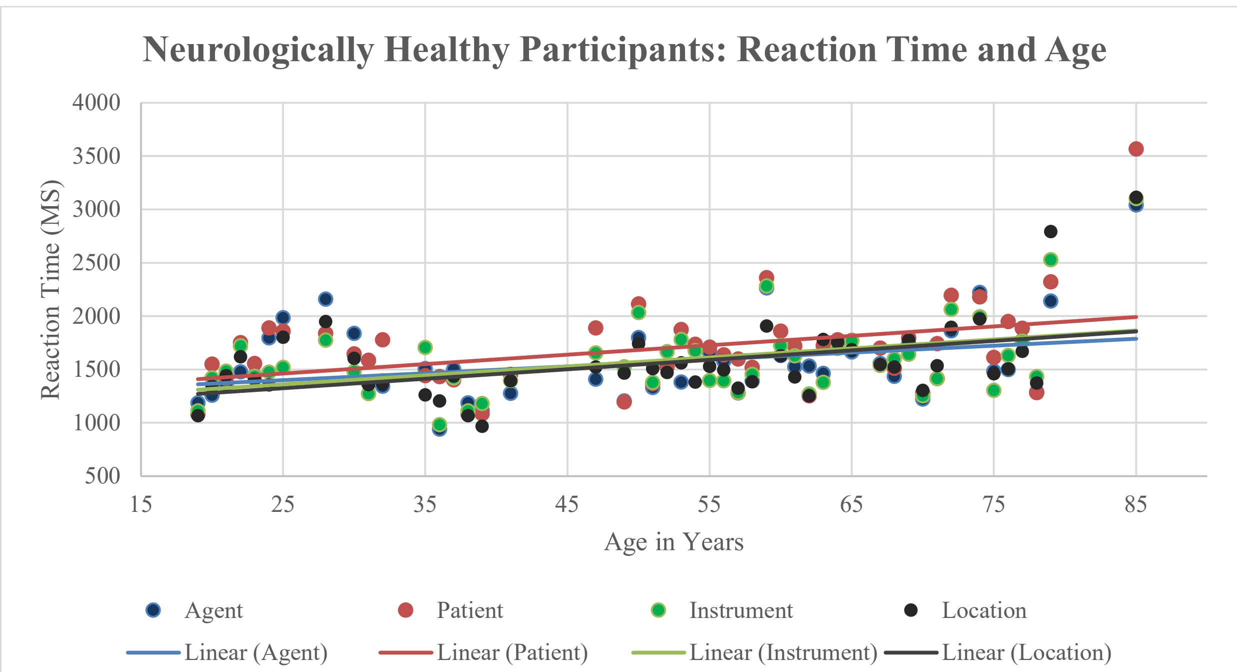

Figure 6: Healthy participants' reaction time performance in relation to age.

3.3.2 Mini-Mental State Examination Analyses

Model glmer(EventAccuracy ~ MMSE*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) assessed the relationship between MMSE Score and the Thematic Hierarchy in relation to accuracy. Figure 7 provides average accuracy performance per event role violation type in relation to MMSE score. MMSE Score did not have a reliable effect on accuracy performance (Estimate = -0.0001468, SE = 0.1550574, p value = 0.999). Similarly, the Thematic Hierarchy did not have a reliable effect on accuracy (Estimate = -1.9259424, SE = 1.2819478, p value = 0.133). There was not a reliable interaction found between MMSE score and the Thematic Hierarchy (Estimate = 0.0617778, SE = 0.0433683, p value = 0.154).

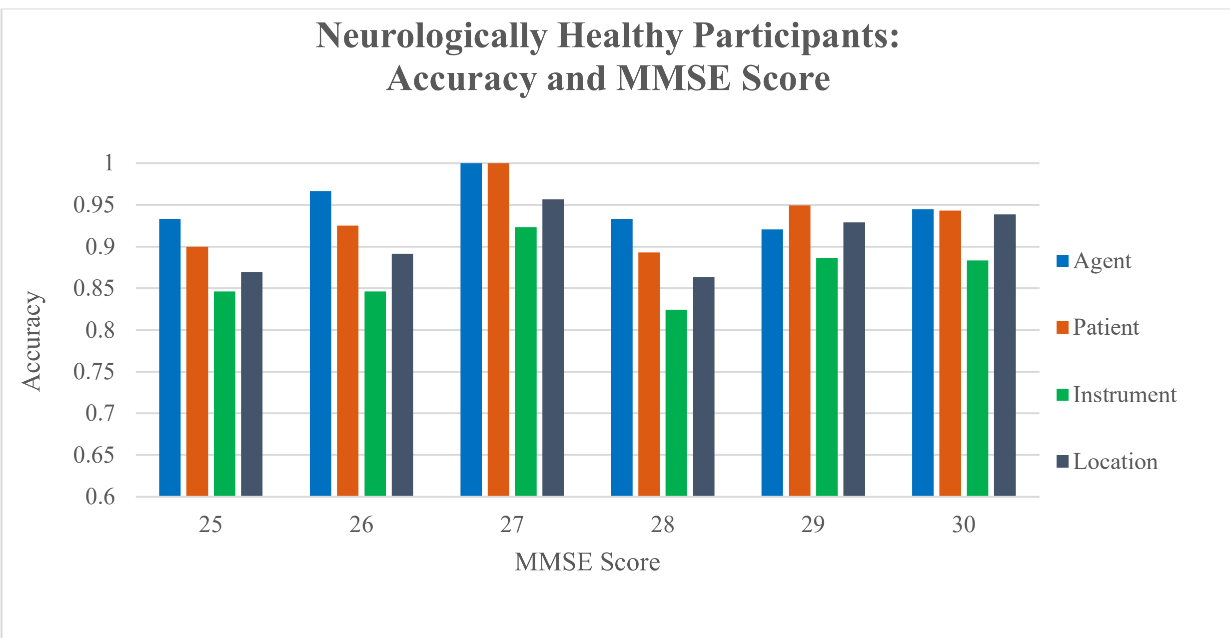

Figure 7: Healthy participants' accuracy performance in relation to MMSE Score.

A linear mixed effects model examined MMSE score and Thematic Hierarchy in relation to reaction time. Model lmer(RT ~ MMSE*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) revealed that participants with an MMSE score of 25 had higher reaction times than participants with MMSE scores of 26-28. Figure 8 provides average reaction time performance per event role violation type by MMSE score. MMSE score had a reliable effect on reaction time (Estimate = -88.520, SE = 43.632, t value = -2.029). Thematic Hierarchy did not have a reliable effect on reaction time (Estimate = -12.306, SE = 186.204, t value = -0.066). There was not a reliable interaction between MMSE and Thematic Hierarchy reaction time (Estimate = 1.543, SE = 6.245, t value = 0.247).

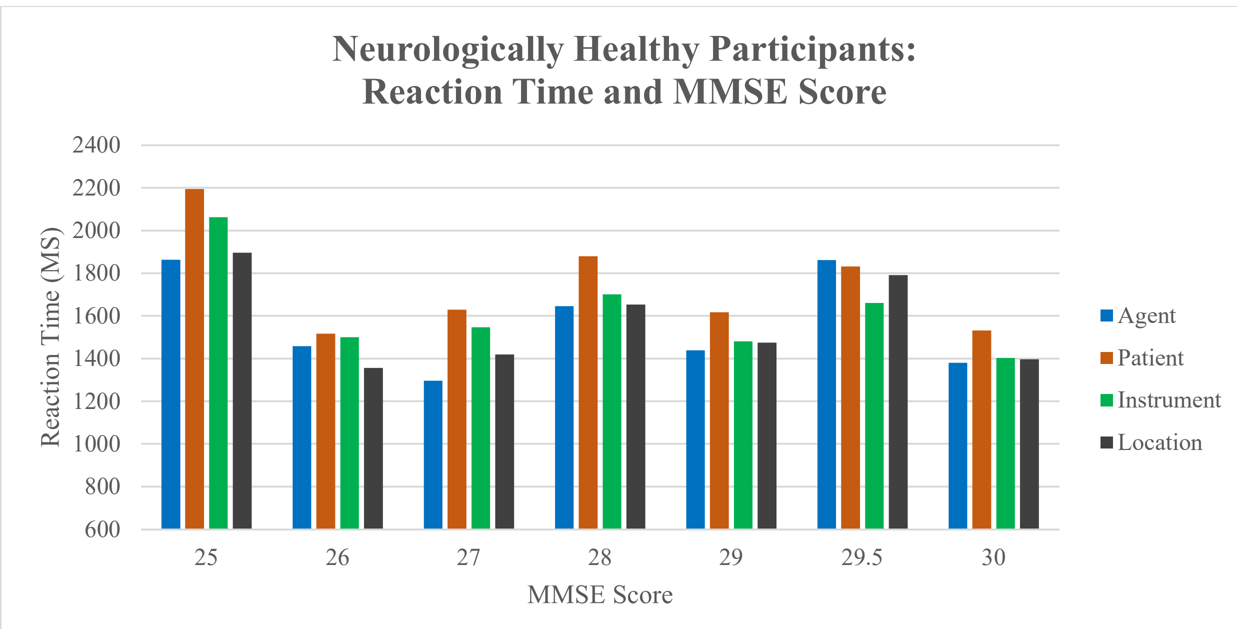

Figure 8: Healthy participants' reaction time performance in relation to MMSE Score.

3.3.3 Years of Education Analyses

A generalized linear mixed effects model examined years of education and Thematic Hierarchy in relation to accuracy. Figure 9 depicts average accuracy performance per event role violation type in relation to years of education. Model glmer(EventAccuracy ~ YoE*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) indicated that participants with 11 years of education were less accurate on all event role violation types than participants with 12-22 years of education. Neither years of education (Estimate = 0.023906, SE = 0.059237, p value = 0.68653) nor Thematic Hierarchy (Estimate = -0.009782, SE = 0.267561, p value = 0.97083) had a reliable effect on accuracy. Additionally, there was no interaction between years of education and Thematic Hierarchy (Estimate = -0.006824, SE = 0.015047, p value = 0.65016).

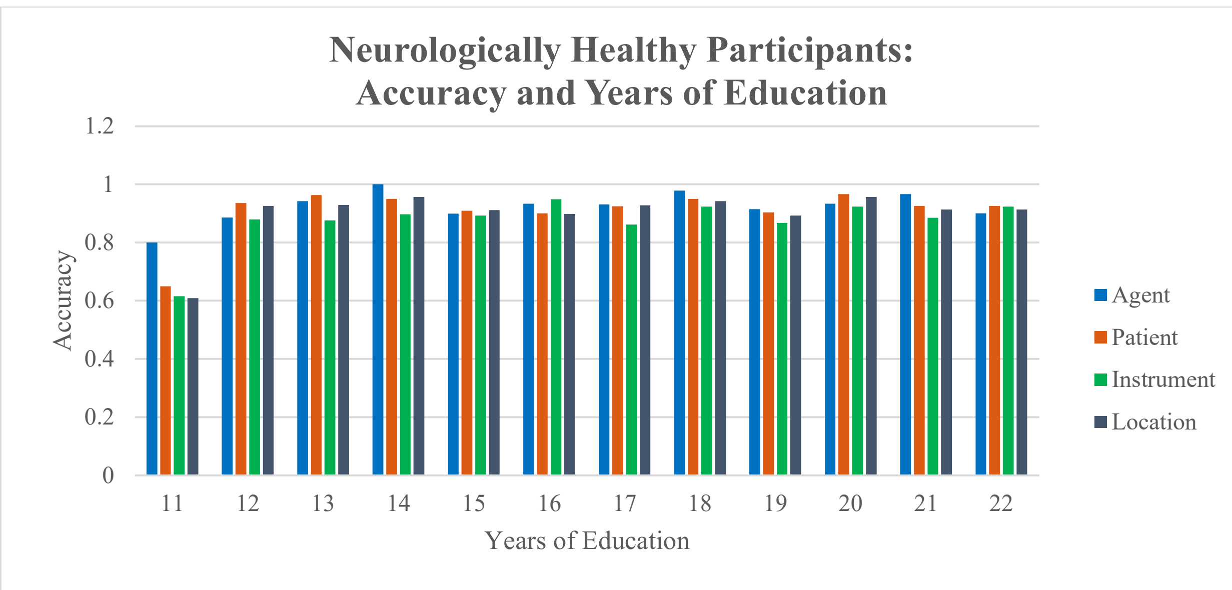

Figure 9: Healthy participants' accuracy performance in relation to years of education.

A linear mixed effects model analyzed how years of education and the Thematic Hierarchy predict reaction time. Figure 10 depicts average reaction time performance per event role violation type in relation to years of education. Model lmer(RT ~ YoE*ThemHierarchy + (1 + ThemHierarchy|Subject) + (1|Stimulus)) found that participants with 11 years of education had higher reaction times than participants with 12-22 years of education. However, years of education did not have a reliable effect on reaction time (Estimate = -3.1859, SE = 17.4183, t value = -0.183). The Thematic Hierarchy did not have a reliable effect on reaction time (Estimate = 42.8134, SE = 46.1222, t value = 0.928). Years of education and Thematic Hierarchy did not have a reliable interaction (Estimate = -0.5739, SE = 2.3879, t value = -0.240).

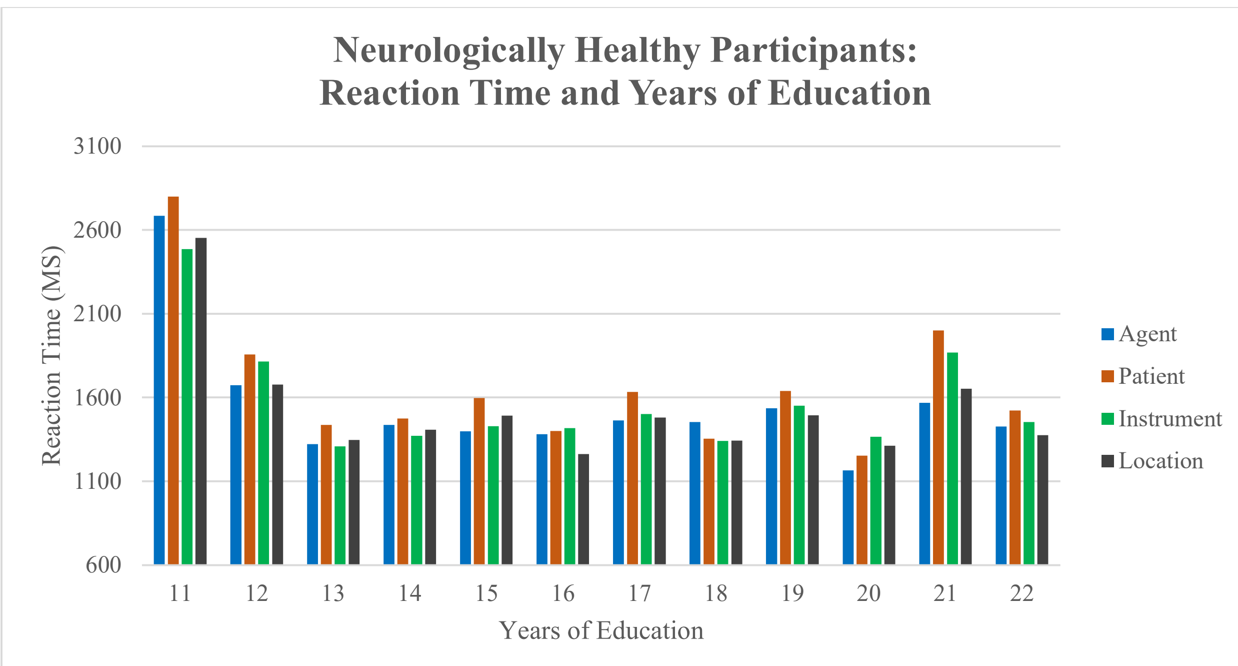

Figure 10: Healthy participants' reaction time performance in relation to years of education.

4.0 Discussion

This paper reports new analyses examining accuracy and reaction time performance of PWA and healthy control participants on incongruent trials of the Event Task. In the task, participants saw photographs of events that are either plausible or implausible and were asked to indicate if the scene depicted is something that may normally happen. Each incongruent stimuli image had at least one event role violation, and accuracy and reaction time performance were analyzed per event role violation type.

I predicted violations that involved event roles from higher on the Thematic Hierarchy would be detected more accurately and more quickly. For example, agent violations were expected to be detected faster and more accurately, whereas location violations were expected to be detected less accurately and more slowly. This prediction was based on experimental evidence from the literature indicating that information about highly prominent event roles, such as agent and patient, is spontaneously encoded even when it is not directly relevant to the task (Hafri et al., 2018). In contrast, event roles at the bottom of the Thematic Hierarchy receive less attention: common instruments are often omitted from story retellings (Lockridge and Brennan, 2002) and locations were the only event role not primed in a single-word priming task (Ferretti et al., 2001).

4.1 PWA and Matched Controls

Analyses of the current dataset did not yield any reliable differences between PWA and healthy controls; however, an interesting numerical pattern of responses was revealed. Both PWA and the healthy control participants displayed the same pattern: patient violations yielded the highest accuracy, followed by agents, locations, and instruments. This is inconsistent with the original hypothesis that agent violations would be most accurate, followed by patient violations, instrument violations, and location violations. On average across both groups, instrument violations were less accurate than other event role violations. In the healthy control group, patient, agent, and location violations were on average between 87% to 88% accurate while instrument violations averaged only 82% accuracy. Similarly, PWA were approximately 83% to 85% accurate on agent, patient, and location violations, while instrument violations were only 76% accurate on average. The majority of PWA were the least accurate in identifying instrument violations in comparison to other event role violation types on the Event Task incongruent trials.

Both PWA and matched healthy participants reacted fastest to location violations, followed by instrument violations, then agent violations, and finally, patient violations. This finding is inconsistent with the hypothesis that both groups would have the lowest reaction time for agent violations, followed by patient violations, instrument violations, then locations violations. These findings indicate that the Thematic Hierarchy does not guide either group's accuracy or reaction time performance on the Event Task. This finding leads to yet another question: if not the Thematic Hierarchy, what is guiding their performance?

Both groups displayed the same pattern of accuracy and reaction time performance, most notably the low instrument event role violation accuracy. One possibility is that the size of the event role in the stimuli image affects accuracy and reaction time performance on the Event Task.

Instruments are often smaller than other event roles, such as agents and locations. Perhaps event roles which take up more pixels of the image, like locations, are easier to identify accurately and quickly in comparison to event roles which are often smaller and take up fewer pixels, such as instruments.

This finding of relatively poor detection of atypical instruments seems to potentially contrast with Lockridge and Brennan's (2002) finding that atypical instruments were often explicitly mentioned early in story retellings, whereas typical instruments were often omitted, suggesting that incongruent or atypical instruments receive more attention than inferable instruments. . However, their study compared typical instruments to atypical instruments, focusing solely on one event role category; in the current study, atypical instruments were compared to atypical agents, patients, and locations. While the Lockridge and Brennan experiment may speak to the prominence of incongruent instruments in comparison to common instruments, our study found that instrument violation accuracy was lower than all other event role violation types, indicating that instruments are not as prominent as agents, patients, or locations.

Additionally, Lockridge and Brennan (2002) examined instrument prominence in story retelling, an act reliant on language comprehension and production. Participants were told the story and then asked to retell it, allowing ample time for story comprehension and the language production necessary for retelling. However, when making plausibility judgements in the Event Task, the participant relies on semantic memory rather than language processing. It might be the case that atypical instruments are prominent enough to receive more attention in language processing, aligning with their position above locations on the Thematic Hierarchy, but perhaps are not prominent enough for quick encoding of information during split-second judgements, such as the plausibility judgement in the Event Task.

4.2 Neurologically Healthy Adults Across the Lifespan

Across the neurologically healthy adult lifespan analyses, Thematic Hierarchy did not have a significant effect on accuracy or reaction time. This finding is similar to the findings for PWA and matched controls in showing that the Thematic Hierarchy does not guide Event Task performance on incongruent stimuli items. Age had a significant effect on accuracy in neurologically healthy adults; increased age was correlated with lower accuracy on the Event Task. Additionally, age had a significant effect on reaction time, indicating that as an individual increases in age, their reaction time gradually slows.

One potential mechanism behind this age-related decline in performance on the Event Task may be inefficiencies in older adults' semantic networks. Semantic networks are the structural organization of mental representations which portray semantic relations in a fashion similar to that of a map. An efficient semantic network would be flexible with strong connectivity and little space between concepts on the map. A study conducted by Cosgrove et al. (2021) examined the effects of aging on semantic networks. They predicted that older adults would display semantic networks with less flexibility, indicating weak connectivity and larger distance between nodes. In their study, neurologically healthy older and younger adults participate in a categorical verbal fluency task. This task measures the ability to recall semantic knowledge from long-term memory, and results from this type of task are often utilized for mapping semantic networks. This data was examined using a percolation analysis to create visualized semantic networks. Findings indicated that older adults' semantic networks were less efficient than those of younger adults (Cosgrove et al., 2021).

In theory, older adults' inefficient semantic networks may hinder performance on a variety of semantic memory tasks, including plausibility judgements such as the Event Task trials. I believe that an efficient semantic network would lead to accurate, fast responses. For example, a younger person with efficient semantic networks may see the Event Task stimulus image of a man playing the violin underwater and quickly identify the incongruent location. Some concepts in a semantic network for the violinist could be a concert hall, orchestra, cello, or musician. However, the concepts of ocean and violinist would not be close to each other on a semantic network, informing the participant that the location must be incongruent. I predict that an older individual with an inefficient semantic network could take longer to conclude that the stimulus is incongruent because their semantic network has more distance between concepts, making the judgement a longer and more strenuous process. I think it is possible that as age increases, performance on semantic plausibility judgements worsens due to inefficient semantic networks.

I also investigated potential relationships between performance on the Mini State Mental Exam (MMSE), an assessment of cognitive function (Folstein et al., 1975), and performance on detecting violations in the Event Task. The MMSE assesses skills relevant to orientation (i.e., knowledge of what year it is), attention, recall, and language. It seemed likely that a person with a lower MMSE score might struggle to attend to the Event Task trials, resulting in low accuracy or high reaction time. In my analyses, MMSE score was not related to accuracy or reaction time performance. However, participants with a MMSE score of 25 had an average reaction time of 2097 MS. Participants with a MMSE score ranging from 26-30 had an average reaction time of 1570 MS. In summary, participants with a MMSE score of 25 were approximately 527 MS slower to respond than participants with a MMSE score ranging from 26-30. MMSE scores classified as "normal" range from 25-30 (Folstein et al., 1975). The slower reaction time of participants with a 25 MMSE score could be indicative of their lower cognitive function, as their score is at the bottom of the normal range.

Years of education also did not have a significant effect on accuracy or reaction time performance. However, participants with 11 years of education were around 60% accurate for most event role violation types, while participants with 12-22 years of education were approximately 90% accurate on most event role violation types. It seems that having 12 years of education increases accuracy performance by nearly 30% in comparison to those with 11 years of education. This finding indicates that having a high school degree is correlated with increased accuracy on the Event Task. Although years of education did not significantly affect reaction time, participants with only 11 years of education displayed remarkably higher reaction time performance. Participants with 11 years of education reacted in 2924 milliseconds (ms) on average. Participants with 12 years of education had a slightly faster reaction time of 1811 ms. Participants with 13-22 years of education displayed a consistently faster reaction time around 1496 ms. Participants with 11 years of education were approximately 1428 ms slower to respond to Event Task trials than participants with 13-22 years of education. This finding reinforces the interpretation that attaining a high school education level may improve performance on the Event Task in relation to both accuracy and reaction time.

One potential explanation for this distinction between 11 years of education and 12+ years of education is that high school coursework may impact the richness of one's semantic memory representations. High school students are exposed to a wide variety of coursework which can provide new insights about the world, adding to their ever-growing semantic memory. It's plausible that high school classes introduce information which adds to their semantic memory and assists in making plausibility judgements. Completing a high school education may be critical in adding important general knowledge to one's semantic memory during a person's formative years. For example, exposure to broader subject matter through various courses could create more efficient semantic networks featuring a wide range of concepts, leading to more accurate and faster responses to plausibility judgements such as the Event Task trials.

Additionally, high school coursework is designed to improve critical thinking and analytical skills. High school assignments, such as analyzing passages in a literature class or solving complex open-response problems in math class, allow students to practice critical thinking on a daily basis, ultimately resulting in improved analytical skills. The Event Task plausibility task is similar to the theoretical questions high school students are often asked to answer in classes; a question is posed, and students use problem solving skills and general knowledge to come to the best possible answer. It's possible that the completion of a high school education leads to improved analytical skills, resulting in better performance on the Event Task in comparison to individuals without a completed high school education.

4.3 Clinical Application

With this research comes the opportunity for future clinical advancements. Verb Network Strengthening Treatment (VNeST) is an aphasia treatment focused on ameliorating generalized word retrieval (both noun and verb retrieval) in PWA (Edmonds et al., 2014). I believe that implementing the Event Task into VNeST protocol could lead a better understanding of how aphasia treatment mitigates event knowledge deficits. Clinicians could utilize the Event Task before and after VNeST to evaluate potential accuracy and reaction time performance improvement, acting as a measure of VNeST's success rates. Additionally, initial Event Task performance could help clinicians identify areas of difficulty (such as specific event role deficits) which could be focused on in treatment. Implementing event role analysis into VNeST could provide useful insight into the ways that PWA process and store event role information, leading to novel clinical applications of VNeST. In the VNeST protocol, the clinician cues the PWA to generate agents and patients as a way of activating their semantic networks, followed by encouraging the expansion of schemas (i.e., where, when, and why is the agent doing that action?). PWA then attempt to independently produce a verb relevant to the event. Finally, the protocol is repeated with the omission of the clinician cues to promote independence. An additional step includes asking the PWA to produce a subject-verb-object sentence describing an event image.

Future research could entail adding eye tracking to this step to examine the order in which PWA look at each event role and the duration of each glance. I would be curious to see if PWA would display a similar pattern of results as to those found by Griffin and Bock (2000). Their eye-tracking data indicated that neurologically healthy adults gazed at the agent before speaking, then glanced at the patient as they began speaking, and concluded by looking to the agent once again. Adding an eye tracking step to VNeST treatment would allow us to examine how/if the order of event role gazing or the duration of gaze changes over the course of treatment. This would expand upon the previous experiment by Griffin and Bock (2000) by tracking PWAs' gazing patterns in relation to all four event role types, whereas the previous study only examined neurologically healthy adults' eye movements for simplistic images featuring only agents and patients. I would predict that, in the beginning phases of treatment, PWA may look between the event roles multiple times prior to speech, spending more time gazing at any event role with which they are struggling with word retrieval. I think that PWA would spend the most time gazing at agents and patients. Additionally, it's possible that PWA may spend less time glancing at instruments, as the current study's results indicate that instruments may not be particularly salient. However, I would expect that over the course of treatment, PWA may begin to show the same pattern as the neurologically healthy participants in the Griffin and Bock (2000) experiment.

Another future direction could entail examining what factors influence generalized lexical retrieval, specifically in relation to event roles and semantic relations. Semantic memory can be divided into two distinct sectors: taxonomic and thematic knowledge. Taxonomic knowledge consists of the relation between two entities founded in similarities such as common features (i.e., dog and cat), whereas thematic knowledge refers to the relationship between two entities which commonly occur in the same events (i.e., dog and leash) (Mirman et al., 2017). Taxonomic organization would separate entities by categories (such as event roles) while thematic organization would distinguish those same entities by events in which they often co-occur (Mirman et al., 2017).

I would expect that PWA would exhibit improved generalized lexical retrieval in response to untrained words that are thematically related to trained words. For example, I predict that a trained word such as "dog" might elicit generalized retrieval for untrained words such as "leash" or "fur" which are thematically related. I hypothesize that generalized lexical retrieval may rely heavily on the richness of one's semantic networks. An efficient, dense semantic network would have less distance between related concepts, which I predict would result in a higher success rate of generalized word retrieval in PWA.

The distinction between thematic and taxonomic relations arises yet another question: could lexical retrieval improvement of trained words result in generalized lexical retrieval across untrained words of the same event role category? For example, perhaps a person trained on the word "hammer" could easily retrieve the untrained word "baseball bat," not because they are thematically related, but because they fall into the same taxonomic category of "instrument" and share the purpose of helping the agent to complete an action. I hypothesize that the success of generalized lexical retrieval across event role types would be dependent on the strength of the participant's semantic networks, more specifically the distance between concepts which are *taxonomically* related instead of thematically related. Efficient, taxonomically organized semantic networks could result in generalized lexical retrieval across event role types.

Future research could examine semantic network efficiency and organization to gain a better understanding of how semantic relations are represented in the mind, answering questions such as: are there taxonomic semantic networks solely detailing the categorization of entities into event roles? Opposingly, do semantic networks display both thematic and taxonomic relations on the same semantic network? If so, I would expect that thematically related concepts would be closer together on the map, whereas taxonomically related concepts would have more distance between nodes. These questions can be addressed in future research delving into how event representations are stored in an individual's semantic memory.

To summarize, examining the gazing patterns of PWA during VNeST treatment could provide useful insight into the ways that PWA process event role information before and during speech. Considering taxonomic relations, thematic relations, and semantic network efficiency could lead to novel findings describing the mechanisms behind generalized lexical retrieval in PWA. In the future, the semantic memory research conducted in relation to the Thematic Hierarchy and event knowledge could lead to the implementation of new and improved treatment methods for those PWA.

4.4 Limitations

A limitation of this research is the variation across stimuli images. The Event Task dataset consists of 256 stimuli images, including both congruent and incongruent stimuli. Among the 128 incongruent stimuli, there are examples of each event role violation type; however, the number of stimuli portraying each event role violation type varies. For example, there were 23 location-exclusive violation stimuli, whereas there were only 13 instrument-exclusive violation stimuli. This severely limited the power of my analyses to detect effects. Additionally, the stimuli images vary in how many event role violations are present. Some Event Task stimuli images include multiple event role violations—for example, a single stimuli image may have both agent and patient violations. Future studies could include a new stimuli set which would ensure that all event role violation types are featured equally across stimuli images and each stimuli image contains only one event role violation. Creating a specialized stimuli set featuring carefully selected event role violations could lead to statistically stronger results in future work.

In addition to the variable number of items per event role violation type, the current study featured only a small number of items. The low number of incongruent stimuli items led to a lack of statistical power in our analyses, resulting in reduced ability to detect meaningful differences between event role violation types. Creating a new stimuli set including equal and larger numbers of items per event role violation type would help to address this limitation in future work.

5.0 Conclusion

The current study examined accuracy and reaction time performance on the Event Task in relation to the Thematic Hierarchy. In summary, the Thematic Hierarchy does not seem to guide Event Task performance in PWA or neurologically healthy adults across the lifespan. However, PWA and neurologically healthy controls alike displayed the same patterns of both accuracy and reaction time performance, indicating that an unknown force may be guiding their performance. Most notably, participants displayed low accuracy performance on instrument violation incongruent trials. This finding could be driven by event role size or lack of instrument prominence when viewing the Event Task stimuli.

Although no results were found to be statistically reliable, interesting numerical patterns emerged from the current study. In neurologically healthy adults, age had a reliable effect on accuracy and reaction time performance, which may be influenced by the deterioration of semantic networks associated with aging (Cosgrove et al., 2021). Additionally, neurologically healthy adults with 12+ years of education were found to have better accuracy and reaction time performance than adults with only 11 years of education, which may be indicative of how high school education completion may impact critical thinking skills and semantic memory richness.

The current study provided novel findings which may be the foundation for future research. Next steps would include creating an improved version of the Event Task featuring stimuli images specifically designed to assess performance on each event role type. Future studies could examine VNeST in relation to the event roles with the hopes of getting a better understanding of how PWA process event roles while simultaneously improving treatment methods. Finally, next steps could include studying the role of semantic networks in regard to aphasia treatment and generalized lexical retrieval. Future research examining PWA and event knowledge is imperative for both the scientific community and the clinical population.

Bibliography

Antonucci, S., & Reilly, J. (2008). Semantic Memory and Language Processing: A Primer. Seminars in Speech and Language, 29(1), 005–017. https://doi.org/10.1055/s-2008-1061621

Bak, T. H., & Hodges, J. R. (2003). Kissing and dancing—A test to distinguish the lexical and conceptual contributions to noun/verb and action/object dissociation. Preliminary results in patients with frontotemporal dementia. Journal of Neurolinguistics, 16(2), 169–181. https://doi.org/10.1016/S0911-6044(02)00011-8

Baker, M.C. (1997). Thematic roles and syntactic structure. In L. Haegeman (Ed.) Handbook of generative syntax (pp. 73–137). Dordrecht: Kluwer.

Bozeat, S., Lambon Ralph, M. A., Patterson, K., Garrard, P., & Hodges, J. R. (2000). Non-verbal semantic impairment in semantic dementia. Neuropsychologia, 38(9), 1207–1215. https://doi.org/10.1016/S0028-3932(00)00034-8

Caramazza, A., & Zurif, E. B. (1976). Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. Brain and Language, 3(4), 572–582. https://doi.org/10.1016/0093-934x(76)90048-1

Cosgrove, A. L., Kenett, Y. N., Beaty, R. E., & Diaz, M. T. (2021). Quantifying flexibility in thought: The resiliency of semantic networks differs across the lifespan. Cognition, 211, 104631. https://doi.org/10.1016/j.cognition.2021.104631

Dresang, H. C., Dickey, M. W., & Warren, T. C. (2019). Semantic memory for objects, actions, and events: A novel test of event-related conceptual semantic knowledge. Cognitive Neuropsychology, 36(7–8), 313–335. https://doi.org/10.1080/02643294.2019.1656604

Edmonds, L., Mammino, K., & Ojeda, J. (2014). Effect of Verb Network Strengthening Treatment (VNeST) in Persons With Aphasia: Extension and Replication of Previous Findings. American Journal of Speech-Language Pathology / American Speech-Language-Hearing Association, 23. https://doi.org/10.1044/2014_AJSLP-13-0098

Ferretti, T. R., McRae, K., & Hatherell, A. (2001). Integrating Verbs, Situation Schemas, and Thematic Role Concepts. Journal of Memory and Language, 44(4), 516–547. https://doi.org/10.1006/jmla.2000.2728

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). “Mini-mental state”: A practical method for grading the cognitive state of patients for the clinician. Journal of Psychiatric Research, 12(3), 189–198. https://doi.org/10.1016/0022-3956(75)90026-6

Griffin, Z. M., & Bock, K. (2000). What the Eyes Say about Speaking. Psychological Science, 11(4), 274–279. https://doi.org/10.1111/1467-9280.00255

Hafri, A., Trueswell, J. C., & Strickland, B. (2018). Encoding of event roles from visual scenes is rapid, spontaneous, and interacts with higher-level visual processing. Cognition, 175, 36–52. https://doi.org/10.1016/j.cognition.2018.02.011

Howard, D., Patterson, K., & Thames Valley Test Company. (1992). The pyramids and palm trees test: A test of semantic access from words and pictures. Thames Valley Test Company.

Jackendoff, R. (1990). Semantic structures. Cambridge, MA: MIT Press.

Lockridge, C. B., & Brennan, S. E. (2002). Addressees' needs influence speakers' early syntactic choices. Psychonomic Bulletin & Review, 9(3), 550–557. https://doi.org/10.3758/bf03196312

McRae, K., & Matsuki, K. (2009). People Use their Knowledge of Common Events to Understand Language, and Do So as Quickly as Possible. Language and Linguistics Compass, 3(6), 1417–1429. https://doi.org/10.1111/j.1749-818X.2009.00174.x

Mirman, D., Landrigan, J.-F., & Britt, A. E. (2017). Taxonomic and thematic semantic systems. Psychological Bulletin, 143(5), 499–520. https://doi.org/10.1037/bul0000092

Proverbio, A. M., & Riva, F. (2009). RP and N400 ERP components reflect semantic violations in visual processing of human actions. Neuroscience Letters, 459(3), 142–146. https://doi.org/10.1016/j.neulet.2009.05.012

Ünal, E., Richards, C., Trueswell, J. C., & Papafragou, A. (2021). Representing agents, patients, goals and instruments in causative events: A cross-linguistic investigation of early language and cognition. Developmental Science, 24(6), e13116. https://doi.org/10.1111/desc.13116