Impaired Coherence for Semantic but not Episodic Autobiographical Memory in Semantic Variant
Primary Progressive Aphasia

Bruna Seixas Lima^{a,b,c} – bruna.seixaslima@mail.utoronto.ca

Brian Levine^{d,e} – blevine@research.baycrest.org

Naida Graham^{a,b,c} – naida.graham@utoronto.ca

Carol Leonard^{a,b,f} – carol.leonard@uottawa.ca

David Tang-Wai^g – david.tang-wai@uhn.ca

Sandra Black^{h,i,j} – sandra.black@sunnybrook.ca

Elizabeth Rochon^{a,b,c} – elizabeth.rochon@utoronto.ca

^a Rehabilitation Sciences Institute, University of Toronto, 160-500 University Ave. M5G 1V7 Toronto, ON, Canada;

^b Department of Speech-Language Pathology, University of Toronto, 160-500 University Ave. M5G 1V7 Toronto, ON, Canada;

^c Toronto Rehabilitation Institute, University Health Network, 550 University Avenue, M5G 2A2 Toronto, ON, Canada;

^d Department of Psychology, University of Toronto, 100 St. George Street, 4th Floor, M5S 3G3 Toronto, ON, Canada;

^e Rotman Research Institute – Baycrest Centre, 3560 Bathurst St, North York, M6A 2X8 Toronto, ON, Canada;

^f Audiology and Speech-Language Pathology Program, University of Ottawa, Guindon Hall 451, Smyth Road Room 3071 K1H 8M5 Ottawa, ON, Canada;

^g Department of Medicine, Division of Neurology, University Health Network Memory Clinic, 399 Bathurst Street M5T 2S8 Toronto, ON, Canada;

^h Sunnybrook Health Sciences Centre, 2075 Bayview Ave, M4N 3M5 Toronto, ON, Canada;

ⁱ Institute of Medical Science, University of Toronto, 1 King's College Cir, M5S 1A8 Toronto, ON, Canada;

^j L.C. Campbell Cognitive Neurology Research Unit, Sunnybrook Health Sciences Centre, 2075 Bayview Ave, M4N 3M5 Toronto, ON, Canada;

Correspondence concerning this article should be addressed to Bruna Seixas Lima, Rehabilitation Sciences Institute, Faculty of Medicine, University of Toronto – 160-500 University Ave., M5G 1V7 Toronto, ON, Canada.email: bruna.seixaslima@mail.utoronto.ca

Declarations of interest: none.

Highlights:

- Patients with svPPA showed deficits in maintaining global coherence of discourse.
- Patients with svPPA showed deficits recalling remote episodic information.
- Deficits in coherence of discourse are observed initially in semantic but not in episodic details.

Abstract

Language deficits, including word-finding difficulties and impaired single-word comprehension, have been found in patients with semantic variant primary progressive aphasia (svPPA). These deficits characterize the linguistic abilities of patients with svPPA on a micro-linguistic level (word and sentence level). On a macro-linguistic level (discourse level), svPPA patients' discourse has been described as "empty". Few studies have considered the contribution of a linguistic impairment to the difficulty of producing autobiographical narratives. In the present study, we assessed svPPA patients' discourse coherence during autobiographical narratives in order to characterize the nature of their speech on a macro-linguistic level and to investigate the relationship between discourse production and memory in a naturalistic context. We collected samples of discourse in which svPPA patients and healthy controls (matched in age, education, sex and handedness) reported autobiographical events. Their narratives were assessed with a rating scale to evaluate global coherence of discourse. The protocols were also analysed using the Autobiographical Interview method (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002) and categorized as episodic (information about events at a specific time and place), semantic (general knowledge), or supplementary details (metacognitive statements, repeated information, editorializing). Where possible, patients were assessed longitudinally at three time points over two years. Patients with svPPA produced a reduced number of episodic details, while the number of semantic details produced was comparable to controls. However,

the episodic information produced by patients was coherent with the topic of discourse, while semantic information was not. These results suggest that svPPA patients produce semantic information comparable to controls in quantity but not quality, whereas the opposite is the case for episodic information.

Keywords: semantic variant primary progressive aphasia; semantic dementia; discourse; coherence; autobiographical memory.

This research was supported by the Canadian Institutes of Health Research (grant numbers 82744 and 130462).

Correspondence concerning this article should be addressed to Bruna Seixas Lima, Rehabilitation Sciences Institute, Faculty of Medicine, University of Toronto – 160-500 University Ave., M5G 1V7 Toronto, ON, Canada.

email: bruna.seixaslima@mail.utoronto.ca

1. Introduction

Semantic variant primary progressive aphasia (svPPA), also known as semantic dementia, is a neurodegenerative condition in which there is progressive degradation of the anterior temporal lobes (ATL) bilaterally and disruption in white matter tracts projecting to the ATL (Agosta et al., 2012; Swindt et al., 2013). Atrophy in the ATL, considered a semantic hub (Patterson et al., 2007; Guo et al., 2013), affects the recall of conceptual knowledge independent of modality (Coccia, Bartolini, Luzzi, Provinciali, & Lambon Ralph, 2004; Hoffman, Jefferies, Ehsan, Jones, & Lambon Ralph, 2012; Guo et al., 2013), while sparing auditory-verbal short-term memory, non-verbal reasoning, perceptual and spatial skills and day-to-day episodic memory (Snowden, Goulding, & Neary, 1989; Hodges, Patterson, Oxbury, & Funnell, 1992). Language deficits in svPPA include fluent aphasia, anomia and impaired single-word comprehension (Gorno-Tempini et al., 2011; Kirshner, 2014).

At the discourse level, production has been described as “semantically empty” (Wilson et al., 2010; Patterson & MacDonald, 2006). Supra-sentential characteristics of language such as discourse production and pragmatic features (e.g. discourse coherence, turn-taking, presupposition, inferencing) have received scant attention in the svPPA literature, in spite of being broadly investigated in other populations such as post-stroke aphasia and Alzheimer’s disease (AD) (e.g. Glosser & Deser, 1990; Nicholas & Brookshire, 1993; Christiansen, 1995; Ulatowska & Olness, 2007; Marini et al., 2011; Andreetta, Cantagallo, & Marini, 2012; Wright & Capilouto, 2012).

In order to produce a narrative, a message must be created before a speaker is able to generate words and sentences (Metteyard & Patterson, 2009). This preverbal message generates suitable propositions, which must be organized into coherent structures and transformed into phonological, lexical, and syntactic structures which will be comprehended by a listener (Marini & Urgesi, 2012). Studies in discourse can focus on analyses of micro-structures and/or of macro-structures. Micro-structures represent the words, phrases and sentences in a given discourse; while macro-structures represent meaning and reference on a global level of discourse. According to discourse theory, the meaning and reference on a global level are built by the constituents of the discourse, but go beyond the individual propositions and sentences (Van Dijk, 1977a). Coherence analyses can focus on local coherence (the semantic link between propositions), or global coherence (the interrelatedness of utterances with respect to a topic of discourse) (Halliday & Hasan, 1976; Van Dijk, 1977a, b). Global coherence of discourse requires the hierarchical organization of units, integration of known facts and concepts, and coordination of a plan leading to a communicative goal, all while maintaining the listener’s perspective. While semantic memory deficits have been linked to impairment in coherence, the relationship between semantic memory and language has been largely attributed to the micro-structural level of language, i.e. the notion that semantic memory impairment can lead to difficulty in word recall (Dijkstra, Bourgeois, Allen, & Burgio, 2004).

Previous studies have found impairments in svPPA related to topic management as demonstrated by increased off-topic utterances (Orange, Kertesz, & Peacock, 1998), word-finding deficits (Ash et al.,

2006), impaired intersentential maintenance of propositions in discourse, cohesion (words linked to a semantic meaning) and informativeness (useful information provided by the speaker) (Rogalski & Edmonds, 2008; Patterson & Mac Donald, 2006; Wilson et al., 2010). The focus of this study is on the relationship of the macro-structures of language, specifically deficits in global coherence, to semantic memory impairment within naturalistic autobiographical narratives. Other studies have previously employed coherence rating scales which vary in length, but invariably measure utterances on a spectrum ranging from coherent to incoherent (Glosser & Deser, 1990; Arbuckle & Gold, 1993; Kurczek & Duff, 2011; Reese et al., 2011; Race, Keane, & Verfaellie, 2015; Van Leer & Turkstra, 1999; Rogalski, Altmann, Plummer-D'Amato, Behrman, & Marsiske, 2010). To our knowledge, none of these rating scales developed so far has considered a score for utterances devoid of information and propositional content, such as fillers, rhetorical questions or repeated information. Here, we also assessed the production of utterances that lack relevant information and therefore might impair overall coherence of discourse, on the view that it may be important to include these utterances in order to properly characterize the discourse of this population.

Autobiographical memory concerns events and facts from one's own life. Autobiographical recall can be dissociated into episodic details (related to an event at a specific time and place) and semantic details (related to general facts about the world and ourselves) (Levine et al., 2002), a distinction that is mirrored in prominent theories of memory based on laboratory tasks (e.g. Tulving, 2002). Episodic and semantic memory interact with each other in supporting autobiographical recall: semantic memory is necessary for setting the contextually-relevant background that supports the retrieval of detailed episodic information (Irish & Piguet, 2013). Numerous studies have delineated specific patterns of autobiographical memory impairment in clinical samples, such as svPPA, mild cognitive impairment (MCI), AD, and amnesia (Graham, Kropelnicki, Goldman, & Hodges, 2003; Moss, Kopelman, Cappelletti, De Mornay Davies, & Jaldow, 2003; Murphy, Troyer, Levine, & Moscovitch, 2008; Rosenbaum et al., 2008; Leyhe, Müller, Milian, Eschweiler, & Saur, 2009; Irish, Lawlor, O'Mara, & Coen, 2010; Sheldon, McAndrews, &

Moscovitch, 2011; Kurczek et al., 2015) and healthy aging adults (e.g. Franklin & Holding, 1977; Levine et al., 2002; St Jacques & Levine, 2007; Addis, Musicaro, Pan & Schacter, 2010; Terret et al., 2016).

While it is generally agreed that day-to-day episodic memory is preserved in svPPA, there is evidence for impaired memory for remote events relative to recent events (i.e. a “reverse gradient” to the recent event impairment characteristic of medial temporal lobe amnesia; Snowden, Griffiths & Neary, 1996; Graham & Hodges, 1997; Nestor et al., 2002; Graham et al., 2003, Piolino, Belliard, Desgranges, & Eustache, 2003; Irish et al., 2011). Others have found the retrieval of remote memories in svPPA to be initially preserved, especially when factors such as autobiographical significance are taken into consideration (Ivanioiu, Cooper, Shanks, & Venneri, 2004; Westmacott, Leach, Friedman & Moscovitch, 2001), though decline is observed over time (McKinnon, Black, Miller, Moscovitch, & Levine, 2006; Maguire, Kumaran, Hassabis, & Kopelman, 2010). Although there is disagreement on the precise nature of episodic autobiographical impairment in svPPA, studies that have quantified episodic and semantic information in free recall have – paradoxically, but consistently – found that svPPA patients produce an excess of certain types of non-episodic information (McKinnon et al., 2006; Irish, Addis, Hodges, & Piguet, 2012a, Irish, Addis, Hodges, & Piguet, 2012b). Peron et al. (2015) have argued that personal semantic information is better preserved than general semantics in svPPA patients, and others found increased general semantic information during recent autobiographical memory recall as well as increased production of extended episodic information (i.e. not specific to a time and place) in comparison to controls during remote autobiographical memory recall (Strikwerda-Brown, Mothakunnel, Hodges, Piguet, & Irish, 2018).

Few studies in the literature of autobiographical memory take into consideration the language component needed for the production of an autobiographical narrative. Autobiographical narratives in svPPA have been rated as overgeneralized, with simplified utterance structure and with elevated use of light verbs and pronouns, without a distinct referent, attributable to impaired retrieval of conceptual information (Meteyard and Patterson, 2009), a conclusion supported by the fact that episodic recall deficits in svPPA are ameliorated by the provision of lexical cues (Moss et al., 2003). These findings are consistent with the

link between language and autobiographical memory as demonstrated in studies of language development (e.g. Fivush and Nelson, 2004; Peterson & Rideout, 1998; Simcock & Hayne, 2002), amnesia due to MTL damage (Duff, Hengst, Tranel, & Cohen, 2009; MacKay, Stewart, & Burke, 1998; Kurczek, Brown-Schmidt & Duff, 2013), AD (Appell, Kertesz, & Fisman, 1982; Martin & Fedio, 1983; Rochon, Waters & Caplan, 1994; Croot, Hodges, Xuereb, & Patterson, 2000; Henry, Crawford, & Phillips, 2004; Taler & Phillips, 2016; Shinagawa, Catindig, Block, Miller, & Rankin, 2016), and MCI (Duong, Whitehead, Hanratty, & Chertkow, 2006; Murphy, Rich, & Troyer, 2006; Fleming, 2014; Drummond et al., 2015).

These findings support the idea of a close relationship between language and memory and suggest that damage to one system is likely to affect the other, yet to our knowledge no studies have attempted to quantify macro-linguistic aspects of discourse production – such as global coherence of discourse – within distinct elements of autobiographical recall. In the present study, we assessed discourse production during the generation of autobiographical narratives. We segmented narrative autobiographical protocols into episodic and semantic categories using a standardized, widely applied method, the Autobiographical Interview (Levine et al., 2002) and subsequently examined global coherence of discourse within these categories.

By assessing patients at three time points, we were able to observe changes in detail recovery and coherence co-occurring with progressive changes to the supporting anatomical systems as expected with progressive neurodegenerative disease. We expected svPPA patients to show reduced episodic (but not semantic) autobiographical recall at Time 1 and that this deficit would progress over serial assessments (for similar findings see Irish et al., 2009; Maguire et al. 2010; McKinnon et al, 2006, 2008). Our critical prediction was that svPPA patients' coherence for semantic information would be impaired across time points in spite of preserved absolute number of semantic details. As we did not have specific predictions about change in coherence over time, this aspect of our analysis was considered exploratory.

2. Methods

2.1 Participants

We report how we determined our sample size, all data exclusions, all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study. Thirty-six participants were recruited for this study. Eighteen svPPA patients were recruited by behavioural neurologists based in four hospitals in Toronto, Canada. Eighteen healthy control participants were recruited from a volunteer participant pool and were matched with patients on the basis of age, education, gender and handedness. The sample size was based upon the patient numbers in the recruitment sites. All participants consented to participate and research ethics approval was obtained for this study at the four hospitals and at the University of Toronto. All participants had English as their native language or were educated in English, and were screened for adequate vision and hearing. Exclusion criteria included a known history of drug or alcohol abuse, or a history of neurological or major psychiatric illness. Data from participants who were not married or did not have children were not included in this study because, as outlined below, the autobiographical memory questions addressed topics relevant to these aspects of life. Patients were diagnosed with svPPA based on clinical and imaging-supported criteria. Clinical imaging with high resolution structural MRI indicated focal temporal lobe atrophy in 17/18 patients. Six had atrophy confined to the left temporal lobe, 7 had bilateral atrophy, left greater than right, 3 had symmetrical bilateral atrophy, and 1 had bilateral atrophy, right greater than left. In one patient, atrophy encroached onto the parietal lobe left greater than right.

Interviews were conducted yearly at three time points, along with a battery of neuropsychological tests. Table 1 shows the results of neuropsychological tests conducted with the participants. The demographic information shows that patient and control groups were matched in age, years of education and gender. The neuropsychological evaluation showed that svPPA patients exhibited impaired single-word production and comprehension (see results from Boston Naming test, Peabody Picture Vocabulary test), semantic memory (Pyramids and Palm Trees test), and delayed episodic recall at all three time points (Rey Complex Figure Recall). Performance on the Rey Complex Figure Recall is known to decline with age (Gallagher & Burke, 2007; Tremblay et al., 2014), and a correlational analysis demonstrated a negative

relationship between participants' age in our sample and the Rey delayed recall results ($r = -.64$, $p < .01$), which may also be related to time since disease onset. Some variation is observed in the measures of working memory and set-switching (Digit-Span and Wisconsin Card-Sorting tasks). The attrition within the groups is presented in Table 2.

Table 1.

Demographic information and neuropsychological testing results.

Measure	Group	Time 1		Time 2		Time 3	
		Mean		Mean		Mean	
Age	svPPA	66.8 (9.3)		68.7 (7.5)		70.2 (8.1)	
	Controls	69.1 (9.0)		74.3(8.1)		76.1 (7.8)	
Years of education	svPPA	16.8 (5.0)		18 (5.4)		20.4 (5.1)	
	Controls	15.9 (3.4)		15.5 (3.6)		15.7 (4.2)	
Male/Female	svPPA	12/6		8/4		5/2	
	Controls	10/8		7/5		5/3	
Estimated Time post onset of disease (months)	svPPA	70.17		79.2 (34.5)		81.5 (25.9)	
MMSE /30	svPPA	20.8 (8.2)	*	19 (8.8)	*	19.6 (9.2)	*
	Controls	29.0 (0.9)		28.9 (1.1)		29.6 (0.7)	
MOCA /30	svPPA	15.9 (6.9)	*	13.7 (6.9)	*	13.3 (5.7)	*
	Controls	26.6 (2.3)		26.6 (2.3)		27.7 (1.5)	
DRS-Mem /25	svPPA	15.4 (6.5)	*	14.6 (5.9)	*	12.1 (7.7)	*
	Controls	23.3 (3.7)		24.3 (0.7)		24.2 (1.2)	
DRS-I/P /37	svPPA	20.2 (8.9)	*	19.8 (9.3)	*	14.5 (10.4)	*
	Controls	37 (0.0)		36.3 (1.6)		36.6 (0.5)	
BNT /60	svPPA	14.8 (11.3)	*	8.4 (5.6)	*	4.6 (4.4)	*
	Controls	53.9 (5.2)		57.4 (1.8)		57.7 (1.6)	
Peabody /204	svPPA	106.2 (56.3)	*	82 (48.0)	*	66.8 (45.4)	*
	Controls	193.8 (8.8)		192.8 (17.3)		197.7 (3.2)	
Rey Recall /36	svPPA	9.7 (8.3)	*	10 (9.0)	*	10.7 (9.7)	*
	Controls	18.4 (6.1)		19.3 (6.2)		21.5 (5.0)	
PPT /52	svPPA	42 (6.5)	*	39.7 (7.6)	*	40.3 (9.8)	*
	Controls	50.6 (1.2)		51.3 (0.8)		51.3 (0.9)	
WCST categories /6	svPPA	2.8 (1.8)	*	3.4 (1.7)		4.6 (0.5)	
	Controls	3.8 (1.1)		4.1 (1.2)		4 (1.4)	

Dig Span- forw	svPPA	6.1 (1.4)		5.9 (1.6)		5.4 (2.2)
	Controls	6.9 (1.0)		7 (0.9)		6.7 (1.3)
Dig Span- back	svPPA	4 (1.4)	*	3.9 (1.2)	*	3.4 (1.9)
	Controls	5 (1.0)		5 (1.1)		5 (1.4)

Note. Results of significance testing below .05 between groups indicated by *. Statistical comparisons are based on results of two-tailed independent samples t-test. MMSE = Mini-Mental State Examination; MOCA = Montreal Cognitive Assessment; DRS-M = Dementia Rating Scale – Memory subscale; DRS-I/P = Dementia Rating Scale – Initiation/Perseveration subscale; BNT = Boston Naming Test; Peabody – Peabody Picture Vocabulary Test; Rey Recall = Rey Complex Figure Test (30-minute delayed recall score); PPT = Pyramids and Palm Trees; WCST = Wisconsin Card-Sorting Task; Dig span forw = Digit span forward; Dig span back = Digit span backward.

Table 2.

Explanation of attrition.

Time	svPPA participants	Controls
1	n=18	n=18
2	n=12 <ul style="list-style-type: none"> Participant withdrew (2) Untestable due to disease severity (2) Study period ended (2) 	n=12 <ul style="list-style-type: none"> Participant withdrew (2) Unable to contact participant (1) Relevant test not administered due to experimenter error (2) Study period ended (1)
3	n=7 <ul style="list-style-type: none"> Study period ended (3) Untestable due to disease severity (1) Participant died (1) 	n=8 <ul style="list-style-type: none"> Participant withdrew (1) Study period ended (3)

2.2 Procedure

No part of the study procedures or analyses was pre-registered in a time-stamped, institutional registry prior to the research being conducted, however a study proposal was presented and approved by a research committee at the University of Toronto. Discourse samples were elicited by asking participants to respond to two autobiographical questions, namely, the description of their wedding day and the day their first child was born. Since our goal was to capture off-topic utterances, participants were allowed to talk without interruption for as long as they wished. The examiner was instructed to probe for information if specific details were not produced and to move on to the next question after the participant stopped talking and remained silent for five seconds. The wedding question included probing about when and where the participant was married, the reception, who the guests were, who the best man was, who the bridesmaids were, and what the participants wore. The question about the birth of the first child included probing about when and where the child was born and how the day started. This procedure is a modified version of the methods described by Kopelman, Wilson, and Baddeley (1989). Given the focus of our investigation (i.e. global coherence of discourse and autobiographical recall), our interview consisted of recalling two specific events from the middle adulthood period in order to ensure an extended stretch of language to address patients' ability to maintain a specific topic of discourse while recalling autobiographical information.

The responses were recorded, transcribed and segmented into propositions, which we will refer to as "details", based on a modified version of the Autobiographical Interview (AI) (Levine et al., 2002). Detail segmentation considered syntactic, prosodic and semantic features, which enabled linguistic analysis. A detail could be a grammatical clause (a subject and a predicate), or a segment external to the clause and able to stand alone as a meaningful unit (see segments from examples below). For purposes of confidentiality, identifying information has been changed in all examples.

2.2.1 Coherence Rating Scale

The details were coded by a rater blind to group membership using a coherence rating scale developed for this study. This scale is consistent with the literature on discourse coherence in fluent

language disorders (Glosser & Deser, 1992; Laine, Laakso, Vuorinen, & Rinne, 1998; Wright, Koutsoftas, Fergadiotis, & Capilouto, 2010; Reese et al., 2011), and was based on the definition of global coherence and linguistic macro-structures by Halliday and Hasan (1976) and Van Dijk (1977a). Each detail received a score from 0 to 3 based on its relatedness to the semantic frame (i.e., the topics “wedding day” and “the day their first child was born”) (see Table 3). The final score was calculated as a weighted average: the sum of scores 0, 1, 2 and 3, divided by the total number of details produced by each participant.

Table 3.

Coherence rating scale

Score	Criteria	Examples
3	Elements of the semantic frame given as a topic of discourse, i.e. information about facts, component states, actions or events directly related to the topic.	<i>/um the best man would have been a friend of mine/</i>
2	Relevant implications for the topic/frame (necessary or probable conditions and consequences, i.e. what happened before or after an event), or a discourse cue supporting the discourse (such as a “yes” or “no” answer to a direct question).	<i>/Who I went to university with back in 1967 to 1973/ /Who now lives in Montreal/</i>
1	Elements which do not belong to the semantic frame nor are relevant for the topic, or repeated information;	<i>/Not Montreal, actually lives in.../ /Where's where's the Olympics going to be this Winter?/ /That's that's where he lives/</i>
0	A detail which carries no propositional information (such as fillers or rhetorical questions).	<i>/You know what I mean?/ /Yeah/</i>

Note. Examples are taken from one participant's responses. Identifying information has been changed.

Reliability on the scoring of the coherence rating scale was conducted on a random sample of 20% of the interviews divided between two secondary raters blinded to group membership. Weighted Cohen's

kappa (κ) was used to determine agreement between the main rater (BSL) and the two secondary raters. There was substantial agreement between the main rater and Secondary Rater 1, $\kappa_w = .804$ (95% CI, .765 to .873), $p < .001$; and the main rater and Secondary Rater 2, $\kappa_w = .819$ (95% CI, .772 to .835), $p < .001$, (Landis & Koch, 1977).

2.2.2 Coherence in Semantic and Episodic Memory

Details were also classified according to the Autobiographical Interview (AI) (Levine et al., 2002) scoring scheme, which separates episodic from non-episodic details. For this study, details were classified as Episodic, Semantic, and Supplementary. Episodic details are defined as reflecting re-experiencing of events specific to a time and place, including happenings, spatial, temporal and perceptual information, and information about internal states (thoughts or feelings). The traditional AI method classifies details as internal (episodic information related to the specific event being recalled) and external. Most external information will be subclassified as non-episodic, however, external episodic information can also be found which relates to episodes that were separate from the main event. As our goal was to assess coherence within episodic versus semantic details, we combined internal details and external episodic details to form a single “episodic” category, even though the external episodic details were from a separate event. This procedure was followed in order to guarantee the coherence scale would not be biased towards episodic information. Details containing semantic information (general facts and knowledge) were classified as Semantic, and the Supplementary category referred to metacognitive statements, inferences, editorializing, repetitions, and incomplete sentences. Once the details were given coherence scores, the Episodic, Semantic and Supplementary sets were generated, and the number of details of each type was tallied. A sample of the analysis of an interview of one svPPA patient is presented in Table 4. The conditions of our ethics approval do not permit public archiving of anonymized study data. Readers seeking access to the data should contact the lead author Bruna Seixas Lima or the Health Sciences Research Ethics Board at the University of Toronto in order to determine the conditions required to be granted access to the data in

accordance with ethical procedures governing the reuse of sensitive data. Sample data with identifying information presented in the manuscript has been edited to preserve anonymity.

Table 4.

Sample of interview

Details	Global coherence	Classification of details		
		Episodic details	Semantic details	Supplementary details
Tell me about the birth of your first child				
Two children	3		1	
they were twins	3		1	
yup	0			1
um and uh that was late one day	3	1		
um and uh the uh doctor was very concerned	3	1		
they were being born	3	1		
and he was concerned	3	1		
that they might be stuck together	3	1		
so after several hours	3	1		
he decided to take them out by surgery	3	1		
um and um my wife was in bad shape	3	1		

but the kids were in pretty good shape	3	1		
yeah	0			1
so when were they born?				
they were born in uh um January 11 th 1975	3	1		
yes	0			1
1975 January 11 th	3			1
one was 5 pounds 4 ounces	3	1		
and the other one was 4 pounds 12 ounces	3	1		
so they were quite small	3	1		
and where did it happen?				
uh that was in Vancouver	3			1
oh sorry	3			1
that was in Toronto	3	1		
can you remember that day? How did it start?				
the day?	0			1
Oh I don't remember very much about the day um	3			1
I remember walking a lot	3	1		
my wife was in the hospital	3	1		
hospital is at the top of	3	1		

streets I can never remember the names um	1			1
just south of Queen Street	3	1		
um just east of Univ- of uh Bay	2	1		
there's a little hospital there	2		1	
and uh we were living at the time up uh	2		1	
about oh maybe three or four miles north of there	2		1	
and um I was walking	3			1
and uh yeah	0			1
they were born late at night	3	1		
and uh after they were born	3	1		
I walked back home again	3	1		
I'm not sure why I didn't drive	1			1
but I didn't	1	1		
Total score	2.38 ^a	23 ^b	5 ^c	12 ^d

Note. Interview conducted with patient svPPA19 at Time 1, illustrating segmentation and coding of details. Identifying information has been changed. ^a Coherence score is calculated as a weighted average; ^b, ^c, ^d number of details are displayed in total counts.

2.3 Analyses

Analyses were conducted using SPSS version 24 at three time points using a 2 x 3 mixed ANOVA in order to test the interaction in number of details between Group (svPPA Patients, Controls) and Type of Details (Episodic, Semantic, Supplementary). A 2 x 3 mixed ANOVA was also used to test the interaction

between Group (svPPA Patients, Controls) and Coherence x Type of Detail (Episodic Coherence, Semantic Coherence, Supplementary Coherence). Post hoc comparisons were Bonferroni corrected ($\alpha = .016$). The analyses were conducted separately for each time period. Additionally, a Spearman Rank-Order correlational analysis was conducted to investigate the relationship between the semantic coherence scores and the standardized Pyramids and Palm Trees (PPT) cognitive test. This analysis aimed at investigating if a relationship could be found between coherence of details in relation to the standardized cognitive scores.

3. Results

3.1 Results at Time 1

3.1.1 Number of Details at Time 1

Three patients and three controls were identified as outliers and their scores were corrected using a standard Winsorization procedure which allows extreme observations to be maintained without influencing statistical estimates or sample sizes (McKinnon et al., 2008). There was no significant main effect of group for total number of details. There was an interaction between Group x Type of detail, $F(2, 34) = 9.36$, $p < .01$, $\eta^2 = .24$. Pairwise comparisons showed that patients produced fewer episodic details than controls ($p < .01$, $\eta^2 = .19$), while producing a comparable number of semantic and supplementary details. Results are shown in Figure 1a .

3.1.2 Coherence at Time 1

There was no significant main effect of Group in the analysis of Coherence per Type of Detail. However, we found an interaction between Group x Coherence per Type of Details, $F(2, 34) = 9.01$, $p < .01$, $\eta^2 = .21$. Pairwise comparisons showed that the svPPA group had a significantly lower coherence score than that of controls in the set of semantic details only ($p < .01$, $\eta^2 = .33$), while the coherence scores of episodic and supplementary details did not significantly differ between groups. Results are shown in Figure 2a.

3.1.3 Correlational analysis at Time 1

Results of the Spearman correlation indicated that there was a significant positive relationship between coherence of semantic details and PPT scores ($r_s(36) = .38, p = .02$).

3.2 Results at Time 2

3.2.1 Total Number of Details at Time 2

There was no statistically significant difference in the total number of details between groups. There was a significant interaction between Group and Type of Detail, $F(2, 34) = 18.21, p < .01, \eta_p^2 = .45$. Pairwise comparisons showed that the svPPA patients produced significantly fewer episodic details ($p < .01, \eta_p^2 = .42$) and marginally more supplementary details than controls ($p = .018, \eta_p^2 = .23$). The difference in number of semantic details was not significantly different between groups. Results are shown in Figure 1b.

3.2.2 Coherence at Time 2

At Time 2 a main effect of Group was found $F(1, 20) = 6.916, p = .016, \eta_p^2 = .25$. However, no significant interaction was found between Group and Coherence per Type of Detail at this time. Given our a priori hypothesis about the differences in coherence between composite sets of details (supported at Time 1), we conducted pairwise comparisons between Group and Coherence per Type of Detail. These again showed that the svPPA group had significantly lower coherence scores than that of controls in the set of semantic details only ($p < .01, \eta_p^2 = .32$) while the coherence scores of episodic and supplementary details did not differ between groups. Results are shown in Figure 2b.

3.2.3 Correlational analysis at Time 2

Comparably to Time 1, results from the Spearman correlation indicated that there was a significant positive association between coherence of semantic details and PPT scores ($r_s(24) = .64, p < .01$).

3.3 Results at Time 3

3.3.1 Total Number of Details at Time 3

The analysis of total number of details did not show a main effect of group. The interaction between Group and Type of Detail, $F(2, 13) = 15.06, p < .01, \eta^2 = .53$ was significant. Pairwise comparisons showed that svPPA patients produced fewer episodic ($p < .01, \eta^2 = .59$) and semantic details ($p < .01, \eta^2 = .45$) than controls. The difference in number of supplementary details was not significant between groups. Results are shown in Figure 1c.

3.3.2 Coherence at Time 3

The analysis did not show a main effect of group. The analysis of Group by Coherence x Type of Detail revealed no significant interaction. Although the overall pattern was qualitatively similar to that observed at the previous time points, none of the pairwise comparisons showed significant differences between groups, possibly due to low power. Results are shown in Figure 2c.

3.3.3 Correlational analysis at Time 3

At Time 3 the Spearman test indicated only a borderline significance between coherence of semantic details and PPT scores ($p = .07$).

Figure 1. Number of Details produced by svPPA patients and controls at Times 1, 2, and 3. The white dot represents the median; the dense vertical line represents the interquartile range; the thin vertical line represents the 95% confidence interval; width of plots reflect the density of observations along the y-axis.

Figure 2. Scores of Coherence x Type of Detail by svPPA patients at Times 1, 2, and 3. The white dot represents the median; the dark vertical line represents the interquartile range; the thin vertical line represents the 95% confidence interval. Width of plots reflect the density of observations along the y-axis.

4. Discussion

The objective of this investigation was to examine the relationship between discourse production deficits and autobiographical memory in individuals with svPPA – particularly concerning coherence of discourse – in order to investigate the relationship between memory and discourse production in this population. Although the overall number of informative units (i.e. details) produced by svPPA patients was not reduced, we found that the patients produced details with lower coherence scores than controls, especially when recalling semantic information (i.e. semantic details). Counting the number of utterances produced is a measure routinely used to evaluate language production. By the same token, counting the number of details produced during autobiographical recollection is a measure routinely used to evaluate memory recall. The findings in our study suggest that a quantitative analysis of the details produced, or the number of utterances, would not on their own have been sufficient to characterize the impairments of this population at early stages. Instead, the combined analysis of both the quantity of details and the coherence of details provided a more complete description of the impairments observed in discourse and autobiographical memory in svPPA patients. The narratives were impoverished by the patients' difficulty in recalling episodic details, which together with the reduced coherence in semantic details likely led to a less vivid description of the event. Results at Time 2 also demonstrated that patients tended to produce more supplementary details than controls, and Time 3 demonstrated that patients tended to produce less episodic and semantic information overall, while producing more supplementary details proportionally.

The analyses carried out at Times 1 and 2 demonstrated that in spite of their semantic memory impairment, the patients tended to produce a similar number of semantic details to controls. However, the semantic details produced by svPPA patients received significantly lower coherence scores than controls, while the other details received comparable coherence scores. These results suggest an important aspect of impairment in autobiographical memory recall in svPPA. The impairment in episodic memory recall was apparent in this cohort, as demonstrated by the reduced number of episodic details produced during the autobiographical narrative. However, the number of semantic details recalled was not initially reduced, in spite of the known semantic memory deficit observed in this population. The current analyses demonstrate

that the impairment of semantic memory may be observed via a different type of analysis: it was captured in the quality of the details produced, instead of the quantity. This may reflect a specific characteristic of svPPA, or it may be an intrinsic distinction in the manifestation of impairments in semantic versus episodic memory. While episodic memory is characterized by spatiotemporal specific processing, semantic memory would be characterized by abstraction of content from various events. The knowledge extracted from this process is managed in high level convergence zones in the brain, which are connected to the large scale autobiographical memory network (Maguire, 2001; Svoboda, McKinnon, & Levine, 2006; Binder, Desai, Graves, & Conant, 2009; Irish & Piguet, 2013). The semantic memory system is diffuse by nature, which may be why impairments in the production of semantic details during autobiographical recall initially present themselves in the form of incoherent, but not reduced, information. It is possible that this distributed circuitry allows for abundant information to be made available, and therefore, impairment in the system may be reflected initially in difficulty selecting relevant information, and inhibiting irrelevant information. This is also corroborated by our findings in the correlational analyses between coherence of details and the standardized PPT test. We found a positive association between coherence of semantic details, and a standardized semantic memory measure, namely the PPT test, at Times 1 and 2, and borderline significance at Time 3. These results suggest that semantic impairment in autobiographical narratives is perceptible in the reduced ability to retrieve appropriate (coherent) information.

Production of a coherent narrative has been linked to the creation of a semantic frame – e.g. circumstances of an event, specification of roles of participants, relationships etc. (Van Dijk & Kintsch, 1983), which has in turn been linked to semantic memory. Fittingly, this study revealed deficits in coherence of discourse in svPPA patients whose impairment is linked to semantic memory. This indicates that semantic memory impairment can lead to deficits in the production of linguistic macro-structures, particularly related to the construction of semantic frames.

Our results confirm – but most importantly expand – previous findings in the literature related to discourse production and autobiographical memory recall by patients with svPPA. As previously

mentioned, earlier studies suggested that svPPA patients exhibit deficits in coherence of discourse when producing extended stretches of language (Rogalski & Edmonds, 2008) as well as difficulties in pragmatic skills (e.g. increased number of off-topic – or incoherent – utterances as demonstrated by Orange et al., 1998). Other studies also found impairments in discourse production in svPPA patients, however these focussed on deficits mostly at the micro-linguistic level of discourse, such as word-finding difficulties (Ash et al., 2006; Patterson & MacDonald, 2006; Wilson et al., 2010), whereas our study has revealed deficits in macro-linguistic features of discourse. Other studies have investigated autobiographical memory recall in patients with svPPA and had previously shown that this group presents with reduced episodic information retrieval (McKinnon et al., 2006, 2008; Irish et al., 2011). The present study is the first study utilizing memory and language measures to investigate autobiographical narratives, and the first to identify a double dissociation between the quantity of details versus coherence of details (i.e. reduced number of episodic details, but preserved episodic coherence; versus preserved number of semantic details, but reduced semantic coherence), a trait which would have gone unnoticed without the combination of the two types of analyses.

It might be argued that semantic memory impairment could lead to deficits in micro-structures of language (such as impaired word retrieval) which could be the underlying cause of the deficit in coherence of discourse we observed, as those difficulties could have been associated with circumlocutions in patients' attempts to recall specific words. The boundaries between macro and micro-linguistic structures are not exact, but the methods used for this study aimed to address the macro-linguistic aspects of discourse production by rating the relevance of the information in each utterance produced during discourse. For that purpose, we created the coherence rating scale which focussed on the semantic content of the propositions uttered during discourse, not on accuracy of lexical retrieval, completeness or syntactic structure. However, in order to further explore the relationship between language and memory and between linguistic micro and macro-structures, we are currently developing a study which will further investigate the influence of the micro-structures of language (i.e. lexical and syntactic features) in the autobiographical narratives of

individuals with svPPA. This study will address whether deficits in micro-linguistic features of discourse are also more prevalent in semantic than in episodic details.

The results of this study also highlight the potential relationship between episodic recall and semantic representations. Autobiographical memory relies on the preservation of episodic memory to retrieve richly detailed information about events at a specific time and place, while the semantic memory system supports retrieval of accumulated general knowledge (Levine et al., 2002). The importance of the interaction between semantic and episodic memory has been highlighted in numerous studies. Tulving (1995, 2001) suggested that semantic memory is an earlier system than episodic memory (i.e. probably evolved first and developed earlier) and, therefore, before information is encoded in the episodic memory system, it is first consolidated in the semantic memory system. The Serial, Parallel, Independent model (SPI) proposes that the encoding of autobiographical memories occurs through a relationship between the semantic and episodic systems. Encoding of memories would be serial (i.e. perceptual information would enter episodic memory through the semantic system), and this information would be stored in parallel systems and traces of a memory could be retrieved independently from the semantic and episodic systems. The SPI model suggests that an individual with brain damage resulting in memory impairment could have difficulty recalling episodic information only, or episodic and semantic information, but not semantic information only. This model is in agreement with our findings (i.e. patients diagnosed with semantic memory impairment have shown difficulty recalling episodic information during autobiographical recall). However, our results demonstrate that even though patients were able to retrieve semantic information, the ability to produce coherent semantic information was impaired.

Others have also suggested that these two systems are part of a continuum, and their interaction is crucial for autobiographical recall; episodic memory recall includes semantic representations (Irish & Piguet, 2013), and, from a neurological perspective, it has been demonstrated that there is considerable overlap between the episodic and semantic memory systems (Burianova, McIntosh, & Grady, 2010). Analogous to the notion of semantic frame in relation to discourse production, it has been suggested that

the semantic memory system may be responsible for creating scenarios which aid in the retrieval of episodic information, necessary both during recall of past experiences and in imagining future possible events (Irish et al, 2012; Irish & Piguet, 2013). The scenario (or frame) sets limits for the context in which an event develops. Therefore, it seems reasonable that deficits in semantic memory could lead to compromised global coherence of discourse. Patients with these deficits may have difficulty creating a circumscribed setting wherein the events to be described develop, and hence may demonstrate a tendency to produce information external to the scenario. It is possible that this difficulty setting the limits of the event may be a cause or be a contributing factor to the difficulty recalling episodic information, as was seen in this study.

In our investigation, the events described were roughly extracted from middle adulthood life periods, which can be considered remote memories, therefore characterizing differences between recent and remote episodic recall in svPPA is beyond the scope of this study. Future studies should investigate if different results would be obtained from analysing memory reports from different life periods, such as childhood (more remote) and more recent events (less remote) in order to investigate if coherence of discourse would also present itself differently depending on epoch. There is evidence that free recall of more recent events is preserved in svPPA (Snowden et al., 1996; Graham & Hodges, 1997; Nestor et al., 2002; Graham et al., 2003; Piolino et al., 2003; Irish et al., 2011). It is possible that had we tested more recent time periods in this sample, the deficit in episodic memory would have been reduced or eliminated. However, this would not have affected our main conclusions that coherence is reduced for semantic and not episodic autobiographical memory in patients with svPPA. As mentioned earlier, others have found episodic memory recall to be spared in svPPA so long as lexical cues are provided, and depending on the autobiographical significance of the events described (Westmacott et al., 2001; Moss et al., 2003). The method of elicitation of discourse in this study aimed at acquiring free speech with minimal intervention from the examiner, hence minimal lexical cues were provided. It is possible we would have found a similar result as previous studies with the provision of lexical cues, however investigating episodic memory difficulties was not the main aim of the present study.

The emotional charge of the events requested in the interviews is also noteworthy. Emotionally loaded events are related to enhanced recall of episodic information (Ochsner, 2000; Schooler and Eich, 2000; Talarico, LaBar, & Rubin, 2004; St. Jacques & Levine, 2007), although emotional autobiographical events have also been observed to contain more semantic or schematic details than neutral memories (Schaefer & Phillipot, 2005). Considering the lack of studies in coherence of discourse of autobiographical narratives, we are unable to predict if different results would have been found in our analyses if we had not requested the report of these events specifically. However future studies should also investigate coherence of discourse in narratives of neutral events in svPPA.

Sex differences have been reported in the literature of autobiographical memory, whereby females were consistently able to retrieve more episodic information than males (Herlitz, Nilsson & Backman, 1997; Seidlitz & Diener, 1998; Pillemer, Wink, DiDonato, & Sanborn, 2003), and emotional memories specifically (Friedman & Pines, 1991; Bauer, Stennes, & Haight, 2003; Bloise & Johnson, 2007). We are not aware of any studies investigating sex differences in autobiographical recall or coherence in dementia or in PPA specifically (see also Viard et al, 2013). We failed to find an effect of sex, although this should be interpreted with caution due to our small sample size.

One limitation of this study is the attrition of participants over time. As the disease progressed, some participants chose to withdraw from the study or became untestable due to disease severity. This particular type of testing makes it unfeasible to test participants who are unable to produce longer samples of discourse. Consequently, the final sample of participants is not identical to the original group. This may be the reason the analysis failed to show significant results in the coherence analysis at Time 3. It is possible that the patient group at Time 3 had better preserved language and memory skills than what would have been observed if we had been able to test the original 18 participants over the three points in time. Furthermore, the smaller group led to reduced statistical power. Another limitation is the use of the same topic of discourse for the three time points (i.e. wedding day and day the first child was born) which can possibly have led to a learning effect and failed to demonstrate decline over time.

5. Conclusion

The current study demonstrated that svPPA patients showed deficits in sustaining the macro-structures of the narrative, which can be seen in the difficulty in maintaining global coherence of discourse. In the analyses of autobiographical memory, we found results which corroborate previous findings in the literature regarding difficulty recalling episodic information. However, the combined analysis of discourse coherence and autobiographical memory demonstrated that deficits in coherence of discourse are observed initially in semantic details, but not in episodic details, leading to a double dissociation in the coherence of discourse of svPPA patients. It is not clear yet whether deficits in coherence of discourse are intrinsically related to semantic memory specifically, or whether impairment in another memory system could cause deficits in coherence which would manifest in different parts of the narrative. One question is whether patients with episodic memory impairment might show deficits in coherence of discourse initially affecting episodic memory. Future analyses will investigate coherence of discourse in autobiographical recall in amnesic mild cognitive impairment patients in order to address this question. Further investigation should also focus on impairment of coherence of discourse in narratives reporting imagined future events in order to reveal more aspects of the relationship between coherence of discourse and the episodic and semantic memory systems.

References

- Addis, D. R., Musicaro, R., Pan, L., & Schacter, D. L. (2010). Episodic simulation of past and future events in older adults: Evidence from an experimental recombination task. *Psychology and aging*, 25(2), 369.
- Agosta, F., Scola, E., Canu, E., Marcone, A., Magnani, G., Sarro, L., ... & Cappa, S. F. (2012). White matter damage in frontotemporal lobar degeneration spectrum. *Cerebral cortex*, 22(12), 2705-2714.

- Andreetta, S., Cantagallo, A., & Marini, A. (2012). Narrative discourse in anomic aphasia. *Neuropsychologia*, 50(8), 1787-1793.
- Appell, J., Kertesz, A., & Fisman, M. (1982). A study of language functioning in Alzheimer patients. *Brain and language*, 17(1), 73-91.
- Arbuckle, T. Y., & Gold, D. P. (1993). Aging, inhibition, and verbosity. *Journal of Gerontology*, 48(5), P225-P232.
- Ash, S., Moore, P., Antani, S., McCawley, G., Work, M., & Grossman, M. (2006). Trying to tell a tale: Discourse impairments in progressive aphasia and frontotemporal dementia. *Neurology*, 66(9), 1405-1413.
- Bauer, P., Stennes, L., & Haight, J. (2003). Representation of the inner self in autobiography: Women's and men's use of internal states language in personal narratives. *Memory*, 11(1), 27-42.
- Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex*, 19(12), 2767-2796.
- Bloise, S. M., & Johnson, M. K. (2007). Memory for emotional and neutral information: Gender and individual differences in emotional sensitivity. *Memory*, 15(2), 192-204.
- Burianova, H., McIntosh, A. R., & Grady, C. L. (2010). A common functional brain network for autobiographical, episodic, and semantic memory retrieval. *Neuroimage*, 49(1), 865-874.
- Christiansen, J. (1995). Coherence violations and propositional usage in the narratives of fluent aphasics. *Brain and Language*, 51, 291-317.

Christianson, S.-Å., & Safer, M. A. (1996). Emotional events and emotions in autobiographical memories. In D. C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 218-243). New York, NY, US: Cambridge University Press.

Coccia, M., Bartolini, M., Luzzi, S., Provinciali, L., & Lambon Ralph, M. A. (2004). Semantic memory is an amodal, dynamic system: Evidence from the interaction of naming and object use in semantic dementia. *Cognitive Neuropsychology*, 21(5), 513-527.

Croot, K., Hodges, J. R., Xuereb, J., & Patterson, K. (2000). Phonological and articulatory impairment in Alzheimer's disease: a case series. *Brain and language*, 75(2), 277-309.

Dijkstra, K., Bourgeois, M. S., Allen, R. S., & Burgio, L. D. (2004). Conversational coherence: Discourse analysis of older adults with and without dementia. *Journal of Neurolinguistics*, 17(4), 263-283.

Drummond, C., Coutinho, G., Fonseca, R. P., Assunção, N., Teldeschi, A., de Oliveira-Souza, R., ... & Mattos, P. (2015). Deficits in narrative discourse elicited by visual stimuli are already present in patients with mild cognitive impairment. *Frontiers in aging neuroscience*, 7, 96.

Duff, M. C., Hengst, J. A., Tranel, D., & Cohen, N. J. (2009). Hippocampal amnesia disrupts verbal play and the creative use of language in social interaction. *Aphasiology*, 23(7-8), 926-939.

Duong, A., Whitehead, V., Hanratty, K., & Chertkow, H. (2006). The nature of lexico-semantic processing deficits in mild cognitive impairment. *Neuropsychologia*, 44(10), 1928-1935.

Fivush, R., & Nelson, K. (2004). Culture and language in the emergence of autobiographical memory. *Psychological science*, 15(9), 573-577.

Fleming, V. B. (2014). Early detection of cognitive-linguistic change associated with mild cognitive impairment. *Communication Disorders Quarterly*, 35(3), 146-157.

Franklin, H. C., & Holding, D. H. (1977). Personal memories at different ages. *The Quarterly Journal of Experimental Psychology*, 29(3), 527-532.

Friedman, A., & Pines, A. (1991). Sex differences in gender-related childhood memories. *Sex Roles*, 25(1-2), 25-32.

Gallagher, C., & Burke, T. (2007). Age, gender and IQ effects on the Rey-Osterrieth complex figure test. *British Journal of Clinical Psychology*, 46(1), 35-45.

Glosser, G. (1993). Discourse production patterns in neurologically impaired and aged populations, Brownell, H., & Joanette, Y (Eds.). *Narrative discourse in neurologically impaired and normal aging adults*, 191-211.

Glosser, G., & Deser, T. (1990). Patterns of discourse production among neurological patients with fluent language disorders. *Brain and language*, 40(1), 67-88.

Gorno-Tempini, M. L., Hillis, A. E., Weintraub, S., Kertesz, A., Mendez, M., Cappa, S. E. E. A., ... & Manes, F. (2011). Classification of primary progressive aphasia and its variants. *Neurology*, 76(11), 1006-1014.

Graham, K. S., & Hodges, J. R. (1997). Differentiating the roles of the hippocampus complex and the neocortex in long-term memory storage: Evidence from the study of semantic dementia and Alzheimer's disease. *Neuropsychology*, 11(1), 77.

Graham, K. S., Kropelnicki, A., Goldman, W. P., & Hodges, J. R. (2003). Two further investigations of autobiographical memory in semantic dementia. *Cortex*, 39(4), 729-750.

Guo, C. C., Gorno-Tempini, M. L., Gesierich, B., Henry, M., Trujillo, A., Shany-Ur, T., ... & Miller, B. L. (2013). Anterior temporal lobe degeneration produces widespread network-driven dysfunction. *Brain*, 136(10), 2979-2991.

- Halliday, M. A., & Hasan, R. (1976). *Cohesion in English*, Longman, London.
- Henry, J. D., Crawford, J. R., & Phillips, L. H. (2004). Verbal fluency performance in dementia of the Alzheimer's type: a meta-analysis. *Neuropsychologia*, 42(9), 1212-1222.
- Herlitz, A., Nilsson, L. G., & Bäckman, L. (1997). Gender differences in episodic memory. *Memory & cognition*, 25(6), 801-811.
- Hodges, J. R., & Patterson, K. (2007). Semantic dementia: a unique clinicopathological syndrome. *The Lancet Neurology*, 6(11), 1004-1014.
- Hodges, J. R., Patterson, K., Oxbury, S., & Funnell, E. (1992). Semantic dementia: Progressive fluent aphasia with temporal lobe atrophy. *Brain*, 115(6), 1783-1806.
- Hoffman, P., Jefferies, E., Ehsan, S., Jones, R. W., & Lambon Ralph, M. A. (2012). How does linguistic knowledge contribute to short-term memory? Contrasting effects of impaired semantic knowledge and executive control. *Aphasiology*, 26(3-4), 383-403.
- Irish, M., Lawlor, B. A., O'Mara, S. M., & Coen, R. F. (2010). Exploring the recollective experience during autobiographical memory retrieval in amnesic mild cognitive impairment. *Journal of the International Neuropsychological Society*, 16(3), 546-555.
- Irish, M., Hornberger, M., Lah, S., Miller, L., Pengas, G., Nestor, P. J., ... & Piguet, O. (2011). Profiles of recent autobiographical memory retrieval in semantic dementia, behavioural-variant frontotemporal dementia, and Alzheimer's disease. *Neuropsychologia*, 49(9), 2694-2702.
- Irish, M., Addis, D. R., Hodges, J. R., & Piguet, O. (2012a). Considering the role of semantic memory in episodic future thinking: evidence from semantic dementia. *Brain*, 135(7), 2178-2191.
- Irish, M., Addis, D. R., Hodges, J. R., & Piguet, O. (2012b). Exploring the content and quality of episodic future simulations in semantic dementia. *Neuropsychologia*, 50(14), 3488-3495.
- Irish, M., & Piguet, O. (2013). The pivotal role of semantic memory in remembering the past and imagining the future. *Frontiers in Behavioral Neuroscience*, 7, Article 27.

Ivanoiu, A., Cooper, J. M., Shanks, M. F., & Venneri, A. (2004). Retrieval of episodic and semantic autobiographical memories in early Alzheimer's disease and semantic dementia. *Cortex*, 40(1), 173-175.

Kirshner, H. S. (2014). Frontotemporal dementia and primary progressive aphasia, a review. *Neuropsychiatric disease and treatment*, 10, 1045.

Kopelman, M. D., Wilson, B. A., & Baddeley, A. D. (1989). The autobiographical memory interview: a new assessment of autobiographical and personal semantic memory in amnesic patients. *Journal of clinical and experimental neuropsychology*, 11(5), 724-744.

Kurczek, J., & Duff, M. C. (2011). Cohesion, coherence, and declarative memory: Discourse patterns in individuals with hippocampal amnesia. *Aphasiology*, 25(6-7), 700-712.

Kurczek, J., Brown-Schmidt, S., & Duff, M. (2013). Hippocampal contributions to language: Evidence of referential processing deficits in amnesia. *Journal of Experimental Psychology: General*, 142(4), 1346.

Kurczek, J., Wechsler, E., Ahuja, S., Jensen, U., Cohen, N. J., Tranel, D., & Duff, M. (2015). Differential contributions of hippocampus and medial prefrontal cortex to self-projection and self-referential processing. *Neuropsychologia*, 73, 116-126.

LaBar, K. S., & Cabeza, R. (2006). Cognitive neuroscience of emotional memory. *Nature Reviews Neuroscience*, 7(1), 54.

Laine, M., Laakso, M., Vuorinen, E., & Rinne, J. (1998). Coherence and informativeness of discourse in two dementia types. *Journal of Neurolinguistics*, 11(1), 79-87.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *biometrics*, 159-174.

- Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: dissociating episodic from semantic retrieval. *Psychology and aging, 17*(4), 677.
- Leyhe, T., Müller, S., Milian, M., Eschweiler, G. W., & Saur, R. (2009). Impairment of episodic and semantic autobiographical memory in patients with mild cognitive impairment and early Alzheimer's disease. *Neuropsychologia, 47*(12), 2464-2469.
- MacKay, D. G., Stewart, R., & Burke, D. M. (1998). HM revisited: Relations between language comprehension, memory, and the hippocampal system. *Journal of Cognitive Neuroscience, 10*(3), 377-394.
- Mackinnon, D. F., & Squire, L. R. (1989). Autobiographical memory and amnesia. *Psychobiology, 17*(3), 247-256.
- Maguire, E. A. (2001). Neuroimaging studies of autobiographical event memory. *Phil. Trans. R. Soc. Lond. B Biol. Sci.* 356, 1441–1451.
- Maguire, E. A., Kumaran, D., Hassabis, D., & Kopelman, M. D. (2010). Autobiographical memory in semantic dementia: a longitudinal fMRI study. *Neuropsychologia, 48*(1), 123-136.
- Marini, A., Andreetta, S., del Tin, S., & Carlomagno, S. (2011). A multi-level approach to the analysis of narrative language in aphasia. *Aphasiology, 25*(11), 1372-1392.
- Marini, A., & Urgesi, C. (2012). Please get to the point! A cortical correlate of linguistic informativeness. *Journal of Cognitive Neuroscience, 24*(11), 2211-2222.
- Martin, A., & Fedio, P. (1983). Word production and comprehension in Alzheimer's disease: The breakdown of semantic knowledge. *Brain and language, 19*(1), 124-141.

- McKinnon, M. C., Black, S. E., Miller, B., Moscovitch, M., & Levine, B. (2006). Autobiographical memory in semantic dementia: Implications for theories of limbic-neocortical interaction in remote memory. *Neuropsychologia*, 44(12), 2421-2429.
- McKinnon, M. C., Nica, E. I., Sengdy, P., Kovacevic, N., Moscovitch, M., Freedman, M., ... & Levine, B. (2008). Autobiographical memory and patterns of brain atrophy in fronto-temporal lobar degeneration. *Journal of Cognitive Neuroscience*, 20(10), 1839-1853.
- Meteyard, L., & Patterson, K. (2009). The relation between content and structure in language production: An analysis of speech errors in semantic dementia. *Brain and language*, 110(3), 121-134.
- Moss, H. E., Kopelman, M. D., Cappelletti, M., De Mornay Davies, P., & Jaldow, E. (2003). Lost for words or loss of memories? Autobiographical memory in semantic dementia. *Cognitive Neuropsychology*, 20(8), 703-732.
- Murphy, K. J., Rich, J. B., & Troyer, A. K. (2006). Verbal fluency patterns in amnesic mild cognitive impairment are characteristic of Alzheimer's type dementia. *Journal of the International Neuropsychological Society*, 12(04), 570-574.
- Murphy, K. J., Troyer, A. K., Levine, B., & Moscovitch, M. (2008). Episodic, but not semantic, autobiographical memory is reduced in amnesic mild cognitive impairment. *Neuropsychologia*, 46(13), 3116-3123.
- Nestor, P. J., Graham, K. S., Bozeat, S., Simons, J. S., & Hodges, J. R. (2002). Memory consolidation and the hippocampus: further evidence from studies of autobiographical memory in semantic dementia and frontal variant frontotemporal dementia. *Neuropsychologia*, 40(6), 633-654.
- Nicholas, L. E., & Brookshire, R. H. (1993). A system for quantifying the informativeness and efficiency of the connected speech of adults with aphasia. *Journal of Speech, Language, and Hearing Research*, 36(2), 338-350.

Ochsner, K. N. (2000). Are affective events richly recollected or simply familiar? The experience and process of recognizing feelings past. *Journal of experimental psychology: general*, 129(2), 242.

Orange, J. B., Kertesz, A., & Peacock, J. (1998). Pragmatics in frontal lobe dementia and primary progressive aphasia. *Journal of Neurolinguistics*, 11(1), 153-177.

Patterson, K., & MacDonald, M. C. (2006). 13 Sweet nothings: Narrative speech in semantic dementia. *From inkmarks to ideas: Current issues in lexical processing*, 299.

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience*, 8(12), 976-987.

Peterson, C., & Rideout, R. (1998). Memory for medical emergencies experienced by 1-and 2-year-olds. *Developmental Psychology*, 34(5), 1059.

Pillemer, D., Wink, P., DiDonato, T., & Sanborn, R. (2003). Gender differences in autobiographical memory styles of older adults. *Memory*, 11(6), 525-532.

Piolino, P., Belliard, S., Desgranges, B., Perron, M., & Eustache, F. (2003). Autobiographical memory and autoneotic consciousness in a case of semantic dementia. *Cognitive Neuropsychology*, 20(7), 619-639. doi:10.1080/02643290242000899

Race, E., Keane, M. M., & Verfaellie, M. (2015). Sharing mental simulations and stories: Hippocampal contributions to discourse integration. *cortex*, 63, 271-281.

Reese, E., Haden, C. A., Baker-Ward, L., Bauer, P., Fivush, R., & Ornstein, P. A. (2011). Coherence of personal narratives across the lifespan: A multidimensional model and coding method. *Journal of Cognition and Development*, 12(4), 424-462.

Rochon, E., Waters, G. S., & Caplan, D. (1994). Sentence comprehension in patients with Alzheimer's disease. *Brain and language*, 46(2), 329-349.

- Rogalski, Y., & Edmonds, L. A. (2008). Attentive Reading and Constrained Summarisation (ARCS) treatment in primary progressive aphasia: A case study. *Aphasiology*, 22(7-8), 763-775.
- Rogalski, Y., Altmann, L. J., Plummer-D'Amato, P., Behrman, A. L., & Marsiske, M. (2010). Discourse coherence and cognition after stroke: A dual task study. *Journal of communication disorders*, 43(3), 212-224.
- Rosenbaum, R. S., Moscovitch, M., Foster, J. K., Schnyer, D. M., Gao, F., Kovacevic, N., ... & Levine, B. (2008). Patterns of autobiographical memory loss in medial-temporal lobe amnesic patients. *Journal of Cognitive Neuroscience*, 20(8), 1490-1506.
- Schaefer, A. and Philippot, P. 2005. Selective effects of emotion on the phenomenal characteristics of autobiographical memories. *Memory*, 13: 148-160.
- Schooler, J. W., & Eich, E. (2000). Memory for emotional events. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory*. New York: Oxford University Press.
- Schwindt, G. C., Graham, N. L., Rochon, E., Tang-Wai, D. F., Lobaugh, N. J., Chow, T. W., & Black, S. E. (2013). Whole-brain white matter disruption in semantic and nonfluent variants of primary progressive aphasia. *Human brain mapping*, 34(4), 973-984.
- Seidlitz, L., & Diener, E. (1998). Sex differences in the recall of affective experiences. *Journal of personality and social psychology*, 74(1), 262.
- Sheldon, S., McAndrews, M. P., & Moscovitch, M. (2011). Episodic memory processes mediated by the medial temporal lobes contribute to open-ended problem solving. *Neuropsychologia*, 49(9), 2439-2447.
- Shinagawa, S., Catindig, J. A., Block, N. R., Miller, B. L., & Rankin, K. P. (2016). When a little knowledge can be dangerous: false-positive diagnosis of behavioral variant frontotemporal dementia among community clinicians. *Dementia and geriatric cognitive disorders*, 41(1-2), 99-108.

Simcock, G., & Hayne, H. (2002). Breaking the barrier? Children fail to translate their preverbal memories into language. *Psychological Science*, 13(3), 225-231.

Snowden, J. S., Goulding, P. J., & Neary, D. (1989). Semantic dementia: A form of circumscribed cerebral atrophy. *Behavioural Neurology*.

Snowden, J. S., Griffiths, H. L., & Neary, D. (1996). Semantic-episodic memory interactions in semantic dementia: Implications for retrograde memory function. *Cognitive neuropsychology*, 13(8), 1101-1139.

St. Jacques, P. L., & Levine, B. (2007). Ageing and autobiographical memory for emotional and neutral events. *Memory*, 15(2), 129-144.

Strikwerda-Brown, C., Mothakunnel, A., Hodges, J. R., Piguet, O., & Irish, M. (2018). External details revisited—A new taxonomy for coding ‘non-episodic’ content during autobiographical memory retrieval. *Journal of neuropsychology*.

Svoboda, E., McKinnon, M. C., & Levine, B. (2006). The functional neuroanatomy of autobiographical memory: a meta-analysis. *Neuropsychologia*, 44(12), 2189-2208.

Talarico, J. M., LaBar, K. S., & Rubin, D. C. (2004). Emotional intensity predicts autobiographical memory experience. *Memory & cognition*, 32(7), 1118-1132.

Taler, V., & Phillips, N. A. (2008). Language performance in Alzheimer's disease and mild cognitive impairment: a comparative review. *Journal of clinical and experimental neuropsychology*, 30(5), 501-556.

Terrett, G., Rose, N. S., Henry, J. D., Bailey, P. E., Altgassen, M., Phillips, L. H., ... & Rendell, P. G. (2016). The relationship between prospective memory and episodic future thinking in younger and older adulthood. *The Quarterly Journal of Experimental Psychology*, 69(2), 310-323.

Tremblay, M. P., Potvin, O., Callahan, B. L., Belleville, S., Gagnon, J. F., Caza, N., ... & Macoir, J. (2014). Normative data for the Rey–Osterrieth and the Taylor complex figure tests in Quebec-French people. *Archives of Clinical Neuropsychology*, 30(1), 78-87.

Tulving, E. (1995). Organization of memory: Quo vadis. In Michael S. Gazzaniga (ed.), *The Cognitive Neurosciences*. MIT Press. pp. 839--847.

Tulving, E. (2001). Episodic memory and common sense: how far apart?. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 356(1413), 1505-1515.

Ulatowska, H. K., & Olness, G. S. (2007, May). Pragmatics in discourse performance: Insights from aphasiology. In *Seminars in speech and language* (Vol. 28, No. 02, pp. 148-158). Copyright© 2007 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.

Van Dijk, T. A. (1977a). Semantic macro-structures and knowledge frames in discourse comprehension. *Cognitive processes in comprehension*, 3-32.

Van Dijk, T. A. (1977b). *Text and context explorations in the semantics and pragmatics of discourse*.

Van Dijk, T. A., Kintsch, W., (1983). *Strategies of discourse comprehension* (pp. 11-12). New York: Academic Press.

Van Leer, E., & Turkstra, L. (1999). The effect of elicitation task on discourse coherence and cohesion in adolescents with brain injury. *Journal of Communication Disorders*, 32(5), 327-349.

Viard, A., Desgranges, B., Matuszewski, V., Lebreton, K., Belliard, S., De La Sayette, V., ... & Piolino, P. (2013). Autobiographical memory in semantic dementia: new insights from two patients using fMRI. *Neuropsychologia*, 51(13), 2620-2632.

Westmacott, R., Leach, L., Freedman, M., & Moscovitch, M. (2001). Different patterns of autobiographical memory loss in semantic dementia and medial temporal lobe amnesia: a challenge to consolidation theory. *Neurocase*, 7(1), 37-55.

Wilson, S. M., Henry, M. L., Besbris, M., Ogar, J. M., Dronkers, N. F., Jarrold, W., ... & Gorno-Tempini, M. L. (2010). Connected speech production in three variants of primary progressive aphasia. *Brain*, 133(7), 2069-2088.

Wright, H. H., Koutsoftas, A., Fergadiotis, G., & Capilouto, G. (2010). Coherence in stories told by adults with aphasia. *Procedia-Social and Behavioral Sciences*, 6, 111-112.

Wright, H., & Capilouto, G. J. (2012). Considering a multi-level approach to understanding maintenance of global coherence in adults with aphasia. *Aphasiology*, 26(5), 656-672.