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Cohesive and coherent connected speech deficits in mild stroke

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ABSTRACT

Spoken language production theories and lesion studies highlight several important prelinguistic conceptual preparation processes involved in the production of cohesive and coherent connected speech. Cohesion and coherence broadly connect sentences with preceding ideas and the overall topic. Broader cognitive mechanisms may mediate these processes. This study aims to investigate (1) whether stroke patients without aphasia exhibit impairments in cohesion and coherence in connected speech, and (2) the role of attention and executive functions in the production of connected speech. Eighteen stroke patients (8 right hemisphere stroke [RHS]; 6 left [LHS]) and 21 healthy controls completed two self-generated narrative tasks to elicit connected speech. A multi-level analysis of within and between-sentence processing ability was conducted. Cohesion and coherence impairments were found in the stroke group, particularly RHS patients, relative to controls. In the whole stroke group, better performance on the Hayling Test of executive function, which taps verbal initiation/suppression, was related to fewer propositional repetitions and global coherence errors. Better performance on attention tasks was related to fewer propositional repetitions, and decreased global coherence errors. In the RHS group, aspects of cohesive and coherent speech were associated with better performance on attention tasks. Better Hayling Test scores were related to more cohesive and coherent speech in RHS patients, and more coherent speech in LHS patients. Thus, we documented connected speech deficits in a heterogeneous stroke group without prominent aphasia. Our results suggest that broader cognitive processes may play a role in producing connected speech at the early conceptual preparation stage.

1. Introduction

Connected speech is a continuous sequence of utterances produced by a speaker to meaningfully convey thoughts and ideas (Crystal, 1980). In connected speech, meaning is conveyed via propositions, the smallest idea unit derived from an utterance containing a subject, verb and modifiers (Mozeiko, Lé, & Coelho, 2010). Propositional speech is connected speech in which the speaker links together propositional units in order to communicate thoughts or ideas that are novel to a specific context (Jackson, 1874).

1.1. Conceptual preparation processes in connected speech

1.1.1. Conceptual preparation

Existing models of speech production emphasise three distinct stages: prelinguistic conceptualisation, linguistic formulation, and articulation and monitoring of the verbal message (Dell, Chang, & Griffin, 1999; Frederiksen & Stemmer, 1993; Garrett, 2000; Jakobson, 1980; Levelt, 1989; Sherratt, 2007). Levelt (1989, 1993, 1999) posited a prelinguistic stage of conceptual preparation, during which a communicative intention is generated (see Sherratt, 2007 for a similar account). At this stage, a speaker attends to the current topic or focus, shifts their attention to new topics as the communicative context demands, and monitors conversation. The result of conceptual preparation is a preverbal message that is not yet linguistic but contains the necessary conceptual structure required for linguistic formulation and articulation. During this stage, macrolinguistic processes organise conceptual information into appropriate propositions by use of linguistic and conceptual-semantic links that connect speech with preceding ideas and the general topic as a whole (Marini, Andreetta, Del Tin, & Carlomagno, 2011). The effective production of meaningful connected speech depends largely on intact macrolinguistic abilities. Such processes include the connection of sentences by means of *cohesion* and *coherence,* which will be the two conceptual processes investigated in the current study (see Fig. 1).

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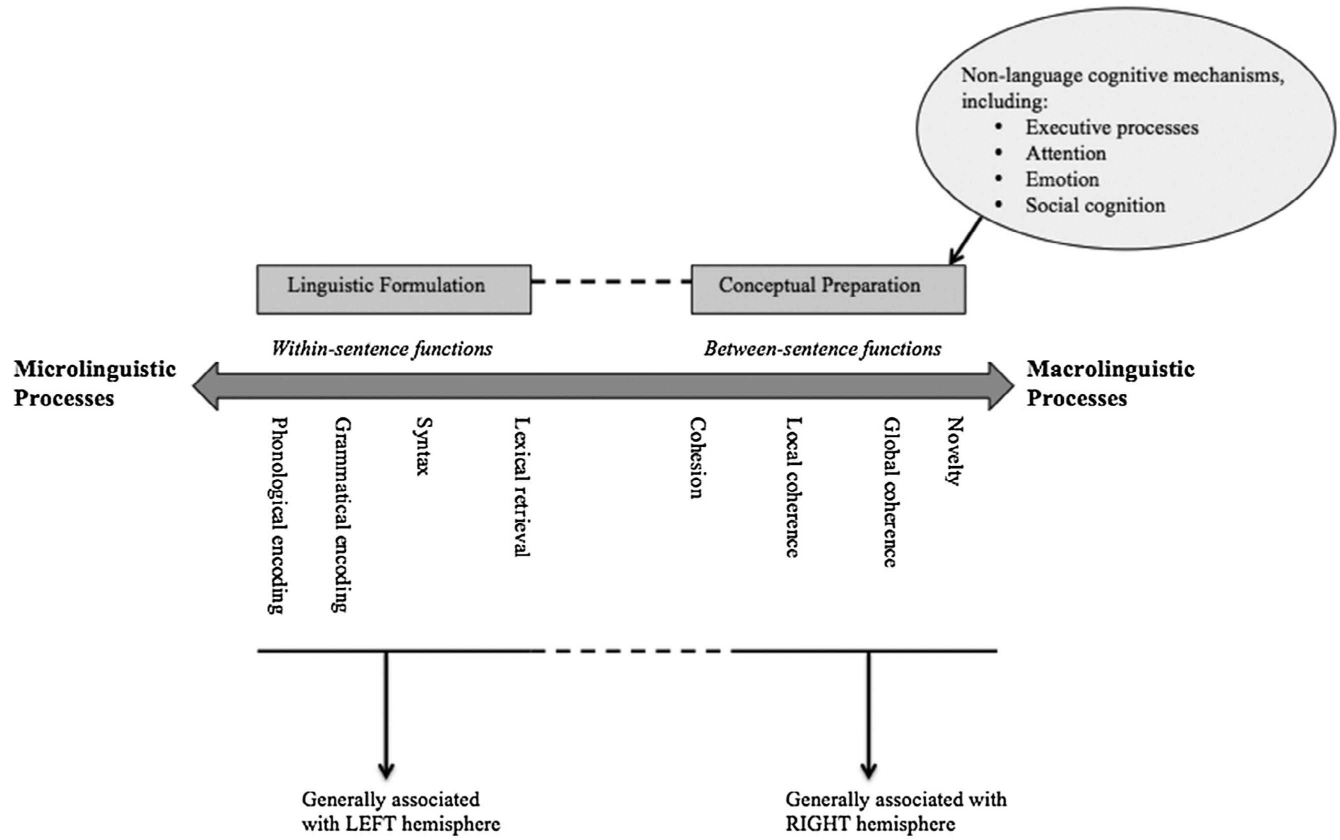

Fig. 1. Schematic representation of key idea generation mechanisms for connected speech production: high level processes. NB This figure does not represent a full model of spoken language production as articulation stages are omitted.

1.1.2. Cohesion

Cohesion is accomplished by the use of *cohesive devices*: linguistic markers that serve to form the structural and semantic connectivity between elements of speech (Halliday & Hasan, 1976). Originally, Halliday and Hasan (1976) described five categories of cohesive devices: reference, conjunctive, ellipsis, substitution and lexical. However, this study will investigate only the three most common cohesive ties in normal narrative speech, which are reference, conjunctive and lexical ties (Mentis & Prutting, 1987) (see Appendix B). A word is considered a cohesive marker if its meaning cannot be adequately interpreted without understanding its relation to some other preceding element of speech (Tanskanen, 2006). A text is considered cohesive if the elements are linked together, but coherent if the sum of the links results in meaningful communication. A text can be cohesive (i.e., accurately linked) but not necessarily coherent (i.e., conveying meaning). Consider the example: The man went to *church* / *Church* rhymes with *birch* / The *birch* tree grew tall and wide. These utterances are cohesively linked but do not form a coherent whole.

1.1.3. Coherence

The ability to maintain thematic unity by integrating propositions or idea units into a coherent representation is often quantified at two levels: local and global (Kintsch & Van Dijk, 1978). *Local coherence* refers to the abstract conceptual links between contiguous utterances that maintain meaning within connected speech. It may be disrupted when there are abrupt changes in topic or missing or erroneous use of reference, for example, the incorrect use of pronouns (Marini, Andreetta et al., 2011). *Global coherence* reflects the degree to which propositions are organised or structured with respect to the overall goal, theme or topic. It involves establishing conceptual links between distal utterances (Marini, Andreetta et al., 2011). Problems maintaining global coherence may manifest as tangential, repetitive or irrelevant speech, or utterances that are conceptually incongruous to the overall topic or story (Christiansen, 1995; Marini, Andreetta et al., 2011; Sherratt & Bryan, 2012).

1.2. Supervisory executive processes and the conceptualisation of connected speech

The link between cognition and language functions has a relatively long history. Almost a century ago, Head (1926) argued for two components of language: the formulation of thought and its skilful expression. The emphasis on "thought" suggests an independent non-language component. Luria noted that impairments in establishing narrative intent mirror action planning deficits, and are related to the frontal lobes (Luria & Tsevtkova, 1968). In 1989, Sohlberg and Mateer suggested that attention-related processes could be implicated in complex language production. More specifically, Alexander (2006) highlighted a role for attention mechanisms in the conceptual preparation stage of spoken language production, and said that to produce connected speech one must "develop an overall communicative goal or intention, sustain activity to reach that goal, monitor progress to the goal, inhibit intrusions that are not relevant to the goal, and be attentive to the listener's expectations and reactions" (p. 236). This is in line with a parallel body of work led by Jefferies and Lambon Ralph on controlled semantic processing, which further highlights the link between executive processes and language by demonstrating that executive control processes are recruited to resolve competition between simultaneously active, semantically-related, representations (e.g., Jefferies, Baker, Doran, & Lambon Ralph, 2007; Jefferies, Hoffman, Jones, & Lambon Ralph, 2008; Jefferies & Lambon Ralph, 2006; Jefferies, Patterson, & Lambon Ralph, 2008).

Three general supervisory "executive" attentional processes, associated with the frontal lobes, were identified by Stuss and Alexander (2007) as critical in language production: (1) energization - initiating and sustaining a response; (2) task-setting - establishing a stimulus-response relationship through trial and error learning; and (3) monitoring - the process of checking a task over time and accordingly adjusting behaviour. These three broad processes may also involve other executive abilities such as selection, inhibition and strategy generation/implementation, for example when task setting or monitoring. In the current study we conceptualise these attentional processes as *sustained attention* and *selective attention*. The processes underlying sustained attention, which is the ability to directly focus and maintain attention for an extended period of time (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996), are (1) the ability to initiate and maintain the intention to respond (i.e. energization – see Robinson, Shallice, Bozzali, & Cipolotti, 2012), and (2) ongoing monitoring of one's actions or evaluation of the task goal in combination with environmental status (i.e. monitoring) (MacPherson, Turner, Bozzali, Cipolotti, & Shallice, 2010). In connected speech, sustained attention is important for idea generation, maintaining the intention to respond, sustaining attention to the discourse focus, and the ongoing monitoring and evaluation of the state of the communicative context and the relevance of what has been, to what may be said (Alexander, 2006; Levelt, 1999; Sherratt & Bryan, 2012). By contrast, selective attention is more "executive" in nature, and involves focussing on one relevant source of information for cognitive processing when multiple competing sources are available (Smith & Jonides, 1999). In connected speech, selective attention is important for choosing ideas or propositional content to be conveyed, while simultaneously inhibiting those irrelevant or unimportant to the discourse focus (i.e. task/goal-setting) (Gold & Arbuckle, 1995; Rogalski, Altmann, Plummer-D'Amato, Behrman, & Marsiske, 2010). It is also important for topic maintenance and appropriate referencing (Coelho, Youse, Le, & Feinn, 2003). Levelt (1999) specified that during conceptualisation the speaker must allocate their attention to a *current focus* or something specific to be expressed (i.e., selective attention). Similarly, Sherratt and Bryan (2012) described how selection and topicalisation of a message requires that the speaker sustain attention to and select the necessary, relevant information from the conceptual structure.

The role of attention during conceptual preparation has also been discussed in the context of dynamic aphasia: a language output disorder characterised by severely reduced propositional language in the context of well-preserved nominal and comprehension language skills. Robinson, Shallice, and Cipolotti (2006) reported patient KAS who presented with sparse, perseverative and echolalic spontaneous speech, which the authors attributed to a deficit in her ability to fluently sequence novel thoughts. The authors speculated that this reflected a deficit in focusing attention on a specific message to be expressed, followed by difficulty in shifting attention to a new message, at the level of conceptual preparation (for similar pattern see also Robinson, 2013). Recently, Robinson, Spooner, and Harrison (2015) reported a similar patient, whose dynamic aphasia was argued to be attributable to difficulty generating ideas, largely resembling an 'energization' deficit. The link between selective attention and the production of propositional speech is also highlighted in other case studies of dynamic aphasic patients who present with a selection deficit in verbal generation (e.g., Robinson, Blair, & Cipolotti, 1998; Robinson, Shallice, & Cipolotti, 2005).

1.3. Lesion studies and neural correlates of connected speech

Generally, the non-language dominant (right) hemisphere is critical in production of speech beyond the sentence level. Patients with right hemisphere damage are documented with impairments in the organisational and informative aspects of connected speech, which impacts on coherence (Bartels-Tobin & Hinckley, 2005; Davis, O'Neil-Pirozzi, & Coon, 1997; Marini, 2012), and relating meaning between utterances, which affects cohesion (Bloom, Borod, Obler, & Gerstman, 1993; Marini, Carlomagno, Caltagirone, & Nocentini, 2005). These right brain damage deficits have been explained by attentional and executive disturbances (Myers, 1997; Sherratt & Bryan, 2012; Tompkins, 1995). In contrast, damage to the language dominant (left) hemisphere results in word and sentence production deficits with relatively preserved global discourse structure (e.g. Marini, Caltagirone, Pasqualetti, & Carlomagno, 2007; Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, & North, 1983). However, patients with left brain damage may also be impaired in the use of cohesion, which has led to the assertion that impaired macrolinguistic abilities in these patients may have a linguistic basis or occur due to difficulties recruiting microlinguistic processes for macrolinguistic purposes (Andreetta, Cantagallo, & Marini, 2012; Andreetta & Marini, 2015). With regard to executive processes, executive dysfunction is the most common cognitive problem following stroke. Executive deficits are reported in just less than half of all stroke patients, and may occur to a degree regardless of stroke location (Nys et al., 2007).

1.4. Current study

To date, the relationship between the conceptual processes of cohesion and coherence in connected speech has not been investigated in a stroke population. This is despite evidence to suggest that connected speech difficulties may be related to impaired attention following stroke. Studies in right hemisphere stroke patients have shown attention and executive functions are associated with coherence and cohesion (Bartels-Tobin & Hinckley, 2005; Sherratt & Bryan, 2012), though no studies to date have investigated the relationship between executive/attention and cohesion/coherence deficits in left hemisphere stroke patients. A clearer understanding of the deficits underpinning connected speech impairments has clinical implications with regard to treatment and rehabilitation.

This study investigated whether stroke patients without aphasia exhibit impairments in cohesion and coherence in connected speech. Being non-aphasic, the stroke group in the current study had largely preserved core language abilities. First, we hypothesised that stroke patients would perform significantly worse on cohesion and coherence measures compared to healthy controls. Secondly, in line with research showing patients with right brain damage have more difficulty with macrolinguistic aspects of speech (e.g., Sherratt & Bryan, 2012) we hypothesised that right hemisphere stroke (RHS) patients would be more impaired relative to left hemisphere stroke (LHS) patients on coherence and cohesion in connected speech. Furthermore, we investigated the role of attention and executive functions in connected speech production. We predicted that stroke patients would be impaired relative to controls on attention and executive function measures, and that these measures would be positively associated with more complete use of cohesion and fewer errors of cohesion and coherence in stroke patients.

2. Method

2.1. Participants

Participants included 18 S patients who met the following criteria: (a) diagnosis of stroke (not TIA) by their treating neurologist; (b) presence of a lesion evident on MRI or CT scan; (c) English as their first language. Patients were excluded if they: (a) had a neurological history other than stroke; (b) had a history of alcohol abuse; (c) were currently experiencing a severe degree of anxiety or depression; or (d) had severe cognitive,[1] vision or hearing impairment that would affect task performance. Stroke patients were not selected based on any specific impairment. The demographic and clinical characteristics of stroke patients are detailed in Law, Young, Pinsker, and Robinson (2015) as the stroke patients were recruited for several studies (also in Appendix A). The stroke group included six patients with left hemisphere lesions, eight right hemisphere lesions and four patients with bilateral damage (see Appendix A).

Stroke patients were matched to 21 healthy controls that had English as their first language and no neurological or psychiatric history. This study was approved by The Prince Charles Hospital and The University of Queensland Human Research Ethics Committees.

As shown in Table 1, the stroke and control groups did not differ significantly in terms of age, gender, years of formal education, or premorbid ability, estimated from reading performance on the National Adult Reading Test (NART – R; Nelson & Willison, 1991) (all $p > 0.05$). Furthermore, the LHS and RHS subgroups did not differ significantly from controls in age, gender or premorbid ability; however, the RHS group had a lower number of years of education than the control group, $p = 0.007$. The right and left stroke subgroups were equivalent in chronicity, $p > 0.05$. The stroke group was not aphasic, as defined by significantly impaired performance on the language baseline tasks (i.e., <5th percentile cut-off). However, one stroke patient (RHS) performed below the 5th percentile in naming and word comprehension.

2.2. Procedure

Participants were administered all baseline and experimental connected speech tasks in one session, with breaks as required. Narrative speech samples were recorded using a Sony ICD-BX112 voice recorder for transcription purposes. The cognitive and language baseline measures assessed the following: current intellectual function (Advanced Progressive Matrices, APM; Raven, 1976); short-term and working memory (Digit Span: WAIS III - Wechsler, 1997); naming (Graded Naming Test - McKenna & Warrington, 1980); single word comprehension (Synonyms Test - Warrington, McKenna, & Orpwood, 1998); sentence repetition (3–6 words in length - McCarthy & Warrington, 1984) and reading (NART-R errors). The complex picture description of the Cookie Theft scene (Boston Diagnostic Aphasia Examination 3rd Edition – Goodglass, Kaplan, & Barresi, 2000) gave a production measure of words spoken per minute and the mean length of utterance (MLU = total narrative words / total sentences – Saffran, Berndt, & Schwartz, 1989). Finally, two word fluency tasks assessed the executive aspect of language function (Benton, 1968): phonemic fluency, where participants were required to generate as many words as possible beginning with the letters F, A and S for one minute each, and semantic fluency, where participants were given one minute to generate as many animals as possible.

2.2.1. Connected speech tasks

Participants were given two self-generated narrative discourse tasks. In the first task, participants were asked to retell the story of Cinderella from memory in as much detail as possible (Saffran et al., 1989). For the second task, participants were asked to talk about any topic of their choice for a maximum of one minute, which followed a period of up to one minute to think of the topic before being prompted to begin. During both speech tasks examiner disruption was minimal with only general encouragement provided (e.g., "Go on", "Mmm").

The speech samples were transcribed and coded by two trained judges. Transcription included all words, sounds and repeats. Contractions were counted as two words (i.e., haven't = have not). Each sample of connected speech was segmented into utterances, that is, a well-formed sentence except where prosodic or phonologic counter indication suggested otherwise (Marini, Andreetta et al., 2011). Acoustic, semantic, grammatical and phonological criteria were used to segment utterances in a successive fashion.

As general guidelines suggest that a corpus of 150–300 words (Bastiaanse & Jonkers, 1998; Saffran et al., 1989) is necessary for adequate speech analysis, a composite score was generated by summing the scores across all variables for the two self-generated narrative tasks (free topic discussion + Cinderella story) to obtain the total number of utterances, and then calculating percentage scores for each variable as a proportion of the total utterances (e.g., total tangential utterances/total utterances × 100).

2.2.1.1. Cohesion. Cohesion was scored using the classification system developed by Halliday and Hasan (1976). Three types of cohesive ties were examined: reference, conjunction and lexical[2] (see Appendix B for operational definitions). The total number of cohesive ties for each category was obtained and each was judged according to their adequacy (adapted from Liles, 1985). Two categories of adequacy were used: (a) *complete*— if the information referred to by the cohesive marker was easily found and unambiguously defined (e.g., The mother is standing at the sink // *she* is washing the dishes); (b) *error*—incomplete such that the information referred to by the cohesive marker was not provided in the text (e.g., Cinderella lived in the castle // *they* had children) or if the listener was guided to ambiguous information elsewhere in the text (e.g., The father and the boy are playing with the ball // *he* is jumping high to catch it). There were seven outcome measures of cohesion: total complete reference ties, total complete conjunctive ties, total reference errors, total conjunctive errors, total complete cohesion (a composite score: complete reference + complete conjunction), total cohesive errors (a composite score: reference errors + conjunction errors) and total complete lexical ties.[3] Each measure of cohesion was expressed as a percentage of the total number of words uttered.

2.2.1.2. Coherence. Coherence was scored along two dimensions: (1) errors in local coherence or the semantic relatedness between contiguous utterances; (2) errors in global coherence or the relatedness of remote utterances with the overall theme or topic

[1] A severe cognitive impairment was defined as cognitive impairment across 2 or more domains (i.e., attention, language, memory, executive function) that was significantly below (>2SDs) premorbid estimates.

[2] First person pronouns (e.g., *I, you*) were not included in the analysis of reference (Halliday & Hasan, 1976). However, when a first person plural pronoun (e.g., *we*) functioned cohesively it was scored as a cohesive device (e.g., in the series of utterances: / My wife was dying / what was I to do / *we* were on our own /, the use of 'we' refers directly to information in the preceding speech).

[3] *Complete lexical ties* were evaluated independently and were not included in total complete cohesion or total cohesive errors scores.

Table 1
Demographic, cognitive and attention/executive function measures for stroke patients and healthy controls: mean (standard deviations and range).

	Group			
		Stroke		
	Controls (n = 21)	All (n = 18)	Left (n = 6)	Right (n = 8)
Demographics				
Sex (M:F)[a]	7:14	11:7	3:3	5:3
Handedness (R:L)[a]	20:1	17:1	5:1	8:0
Age[b]	64.2 (7.6; 49–79)	65.8 (10.7; 47–84)	66.5 (12.0; 54–84)	62.0 (8.4; 47–73)
Education[c]	13.6; 2.8; 10–19)	13.3 (3.6; 9–23)	13.8 (2.8; 9–16)	11.4 (1.8; 10–15)**
Chronicity[d]	–	284.5 (167.9; 44–684)	281.7 (134.7; 124–494)	344.6 (192.1; 94–684)
Cognitive and Language Baseline				
Premorbid Ability (NART-derived FSIQ)	109.8 (7.7; 94–122)	102.6 (13.2; 77–123)	104.6 (14.8; 84–123)	100.3 (13.5; 77–123)
Progressive Matrices (/12)	7.4 (2.6; 2–12)	5.7 (3.0; 1–11)	7.3 (2.6; 5–11)†	3.7 (2.2; 1–6)*
Digit Span				
Forwards	10.6 (2.1; 7–14)	9.9 (2.1; 5–14)	8.8 (2.1; 5–11)	10.9 (1.9; 8–14)
Backwards	6.9 (2.2; 5–10)	5.5 (1.7; 3–9)	5.5 (1.5; 4–8)	5.6 (1.6; 3–8)
Total	17.4 (4.0; 13–24)	15.2 (2.9; 10–20)	14.3 (2.7; 10–18)	16.5 (3.0; 11–20)
Graded Naming Test (/30)	21.8 (3.9; 14–28)	18.0 (4.2; 10–25)**	19.8 (4.4; 13–25)	15.6 (3.7; 10–21)*
Synonyms Test (/50)	45.1 (3.9; 37–50)	39.1 (5.1; 29–47)***	41.6 (5.0; 34–47)	36.6 (4.4; 29–41)**
Sentence repetition (/10)	9.9 (0.3; 9–10)	10.0 (0.0; 10–10)	10.0 (0.0; 10–10)	10.0 (0.0; 10–10)
NART reading errors (/50)	16.9 (6.3; 7–30)	22.6 (10.7; 6–43)	21.0 (12.1; 6–38)	24.4 (10.9; 6–43)
Word Fluency				
Phonemic (FAS)	49.0 (11.0, 26–72)	22.7 (10.3; 7–46)***	18.2 (6.8; 9–28)***	28.5 (11.3; 15–46)
Semantic (Animals)	19.1 (5.6; 8–31)	15.0 (3.8; 6–20)	14.2 (3.5; 11–19)	15.6 (4.7; 6–20)
Cookie Theft scene				
Words per minute	134.3 (35.7; 58–182)	99.2 (37.6; 25–184)**	91.2 (39.3; 25–128)	103.1 (44.6; 60–184)
Mean length of utterance	7.9 (1.0 (6.4; 9.1)	6.7 (0.8; 5.3–9.0)***	7.1 (1.0; 6.3–9.0)	6.3 (0.7; 5.3–7.1)**
Attention/Executive Function Tasks				
Attention Tasks				
Elevator Counting (/7)	6.8 (0.5; 5–7)	6.2 (1.1; 3–7)	6.5 (0.5; 6–7)	5.9 (1.6; 3–7)
Elevator Counting with Distraction (/10)	7.5 (3.2; 1–10)	5.0 (3.4; 0–10)*	7.0 (3.0; 2–10)	3.1 (3.2; 0–10)*
Hayling Sentence Completion				
Overall SS	5.1 (1.8; 1–8)	3.0 (2.1; 1–8)**	2.7 (2.1; 1–6)	3.6 (2.3; 1–8)
Initiation RT SS	5.7 (0.8; 3–7)	5.0 (1.1; 3–6)	4.2 (1.3; 3–6)	5.4 (0.5; 5–6)
Suppression RT SS	5.0 (1.7; 1–7)	3.2 (2.0; 1–8)**	2.5 (2.3; 1–6)	3.7 (2.2; 1–8)
Suppression Error SS	5.5 (2.2; 1–8)	3.2 (2.5; 1–8)**	3.3 (3.2; 1–8)	3.3 (2.4; 1–7)

Note. NART FSIQ = National Adult Reading Test Predicted Full Scale IQ; SS = Scaled Score; Hayling Overall SS Range 1–10, Initiation SS Range 1–7, Suppression/Suppression Error SS Range 1–8, 6 = Average. [a]Scores for sex and handedness represent ratio (not mean) scores. [b]Age in years. [c]Education in years. [d]Chronicity (time since stroke) in days. Significant difference from controls following Bonferroni correction, *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. Significant difference from left stroke †$p < 0.05$. Four stroke patients were excluded from L vs R analyses due to bilateral damage (see Appendix A). NB: For subgroup comparisons (i.e. left and right stroke vs. controls), a closely matched smaller control group was used (n = 8).

(Marini, Andreetta et al., 2011). The total number of topic switches and missing referents (as per Marini, Galetto et al., 2011) were added to create a total number of local coherence errors, which was then expressed as a percentage of the total number of utterances. As local coherence overlaps with application of referential cohesion it is important to differentiate when errors of cohesion and local coherence could be considered independent. Take the example of the cohesive errors given previously, Cinderella lived in the castle // *they* had children, could also be considered an error of local coherence as it contains a missing referent and an abrupt topic shift. The second example (i.e., The father and the boy are playing with the ball // *he* is jumping high to catch it) would be considered a cohesive error only. Another example of a failure of local coherence is evident in the utterances: / they put it... / he went to the local doctor /. The first utterance remains unfinished while in the second utterance new information is introduced (topic switch) and a cohesive error occurs.

Errors of global coherence include utterances that are tangential, conceptually incongruent with the story, propositional repetitions, or filler sentences (Marini, Andreetta et al., 2011; see also Christiansen, 1995). An utterance was considered: (1) tangential when it contained a derailment in the flow of discourse with respect to the information already provided in a preceding utterance; (2) conceptually incongruent when it included ideas not directly addressed by the task; (3) a propositional repetition where the speaker repeated ideas, showing a lack of novelty, or directly restated utterances, reflecting perseveration; and (4) a filler utterance when it was an empty phrase that did not provide any additional information to the overall task or was a direct comment about the nature of the task. The total number of tangential sentences, conceptual incongruence errors, propositional repetition errors and filler sentences were expressed as percentages of the total number of utterances. Finally, the number of propositional repetitions, tangential, conceptually incongruent, and filler utterances was totalled and expressed as a percentage of the total number of utterances to yield an index of global coherence errors. Thus, there were six outcome measures of coherence: local coherence errors, propositional repetitions, tangential utterances, conceptually incongruent utterance, filler sentences, and global coherence errors (a composite measure: propositional repetitions + tangential utterances + conceptually incongruent utterance + filler sentences).

2.2.2. Attention and supervisory executive function tasks

Attention was measured using the Elevator Counting and Elevator Counting with Distraction subtests from the Test of Everyday Attention (TEA - Robertson et al., 1996). *Elevator Counting* (EC) is a measure of sustained auditory attention, which requires the participant to count strings of tones. *Elevator Counting with Distraction* (ECD) is a more complex selective attention and auditory-verbal working memory task. It requires the participant to count a series of low tones while ignoring interspersed high tones. Verbal initiation and suppression were measured using the Hayling Sentence Completion Test (Burgess & Shallice, 1997), whereby the participant is read aloud a short sentence with the final word omitted, and asked to give a single word to complete the sentence. This is either a sensible word (initiation - Section A; e.g. "When you go to bed, turn off the ... *light*"), or an unconnected word (suppression - Section B; e.g., in this example ... *banana*"). The Hayling was administered in accordance with the published manual (Burgess & Shallice, 1997). The Initiation RT and Suppression RT Sub-scaled Scores (SS) were derived from the total response times (RT) for Sections A and B, respectively. The Suppression Error SS was derived from the number of 'blatant' and 'subtle' errors produced in suppression of a natural completion in Section B. These three SSs were then combined to form the Hayling Overall SS, which ranges from 1 to 10 and corresponds to percentiles (e.g., a SS of 6 corresponds to the 50th percentile and is indicative of average ability in initiation and suppression). The Hayling task was chosen to measure supervisory executive functions of interest because it is comprised of sentences and context and is therefore most relevant to connected speech. The Hayling task affords a measure of verbal initiation in a semantic context (Section A) and verbal suppression, which reflects the executive process of inhibition in a language context (Section B). Healthy controls are typically unimpaired for both the initiation and suppression sections (e.g., Burgess & Shallice, 1996). By contrast, patients with focal frontal lesions are reported to be unimpaired on the initiation section but impaired on the inhibition section (Errors and RTs) (Burgess & Shallice, 1996; Robinson, Cipolotti et al., 2015). Thus, we predict that stroke patients will be impaired on the suppression but not initiation sections, resulting in decreased Overall SS, Suppression RT SS and Suppression Error SS relative to controls. Moreover, performance on the Hayling task has been linked to "monitoring" (e.g., Hornberger & Bertoux, 2015), which is one of three attentional processes that comprise Stuss and Alexander's (2007) framework of "supervisory" attention.

2.3. Statistical analyses

The stroke and control groups were compared on all measures using Bonferroni-corrected independent *t*-tests. Violations to homogeneity of variance were corrected using Levene's adjusted degrees-of-freedom or, in the case of severe violations, the non-parametric Mann-Whitney *U* test was conducted. The chi-square test of independence was used for categorical data (e.g., gender). One-way Analysis of Variance (ANOVA) and Bonferroni-corrected *t*-tests were used for subgroup analyses (LHS, $N = 6$ versus RHS, $N = 8$ versus controls). At the subgroup level, a smaller control group ($N = 8$) was used for comparison to avoid confounds due to group size differences. This group was closely matched to the left and right hemisphere stroke groups on age, sex, education and premorbid IQ. Given the lower education of the RHS group, years of education was entered as a covariate in the analyses of cohesion and coherence. Four patients were removed from the subgroup analyses, due to lesions affecting both hemispheres ($N = 2$), or patients having bilateral white matter changes that were more prominent than their focal lesions ($N = 2$) (see Appendix A). In cases where the assumption of equal variances was violated, the non-parametric Kruskal-Wallis test was used followed by Mann-Whitney *U* tests. In addition, non-parametric Spearman rank correlation coefficients were undertaken between connected speech and attention/executive measures for the variables for which stroke patients were impaired. The LHS group performed very close to ceiling on both attention measures, which precluded interpretation of correlations**.** Therefore, correlations were only undertaken between attention and connected speech measures for the stroke group as a whole and the RHS group. For the executive measures, correlations were performed for the whole stroke group and both subgroups.

3. Results

3.1. Cognitive and language baseline

A summary of cognitive and language baseline measures is presented in Table 1. On cognitive baselines, there was no significant difference between the whole stroke group and control group on Digit Span (forwards: $t(23) = 0.67$, $p > 0.05$, $d = 0.29$; backwards: $t(23) = 1.66$, $p > 0.05$, $d = 0.69$; total: $t(23) = 1.54$, $p > 0.05$, $d = 0.63$) or the Advanced Progressive Matrices, $t(35) = 1.85$, $p > 0.05$, $d = 0.60$. However, the RHS group performed significantly below the control and LHS groups on the Matrices ($t(12) = 2.36$, $p < 0.05$, $d = 1.32$ and $t(10) = 2.67$, $p < 0.05$, $d = 1.56$, respectively). For the language baseline tests, comparisons were Bonferroni corrected for seven linguistic variables. The stroke and control groups did not differ significantly on measures of sentence repetition, $t(37) = 1.34$, $p > 0.05$, $d = 0.47$ or single word reading, $t(33) = 1.96$, $p > 0.05$, $d = 0.60$. On the Graded Naming Test, stroke patients named significantly fewer objects than healthy controls, $t(37) = 2.94$, $p < 0.01$, $d = 0.94$. Although the subgroup ANOVA was not significant, $F(2,19) = 4.33$, $p > 0.01$, $\eta_p^2 = 0.31$, *t*-tests revealed that the RHS group named significantly fewer objects than controls, $t(14) = 2.97$, $p < 0.05$, $d = 1.49$. This may reflect the lower education level of the RHS group; thus, education was controlled for in the cohesion/coherence analyses. Stroke patients performed significantly below controls on the Synonym Test, $t(35) = 4.08$, $p < 0.001$, $d = 1.32$. Subgroup analysis confirmed this, $F(2,17) = 7.67$, $p < 0.01$, $\eta_p^2 = 0.47$, and *t*-tests revealed that the RHS group scored lower than healthy controls, $t(13) = 4.19$, $p < 0.01$, $d = 2.15$. The stroke group produced significantly fewer words than the control group on the Cookie Theft Scene description, $t(37) = 2.99$, $p < 0.01$, $d = 0.95$, however, subgroup analysis was not significant, $F(2,19) = 0.97$, $p > 0.05$, $\eta_p^2 = 0.09$. On the Cookie Theft task, the mean utterance length was shorter for the stroke group than the controls, $t(37) = 4.04$, $p < 0.001$, $d = 1.30$. Subgroup analysis confirmed this, $F(2,19) = 7.06$, $p < 0.01$, $\eta_p^2 = 0.43$, with the RHS group producing a significantly shorter mean length of utterance than controls, $t(14) = 4.00$, $p < 0.01$, $d = 1.98$. The stroke group as a whole performed significantly below the control group on the phonemic word fluency task, $t(37) = 7.64$, $p < 0.001$, $d = 2.46$, but not the semantic word fluency task, $t(37) = 2.60$, $p > 0.01$, $d = 0.84$, which confirms a degree of executive language difficulty in this group. Subgroup analysis revealed that the LHS group generated significantly fewer words than controls on phonemic fluency, $t(12) = 4.40$, $p < 0.01$, $d = 2.48$.

3.2. Cohesion and coherence in stoke patients vs. controls

3.2.1. Cohesion

A summary of cohesion connected speech measures is presented in Table 2 (see also Fig. 2). Bonferroni corrections were applied as follows: measures of complete cohesion were corrected for three variables (complete reference ties, complete conjunctions, complete lexical ties), measures of errors of cohesion were corrected for two variables (reference errors and conjunctive errors), and composite scores of cohesion were corrected for two variables (total complete cohesive ties, total cohesive errors). As hypothesised, stroke patients used significantly fewer complete cohesive ties, $t(29) = 5.02$, $p < 0.001$, $d = 1.78$, and made more cohesive errors overall, $t(16) = 3.65$, $p < 0.01$, $d = 1.39$, compared to healthy controls. Stroke patients used fewer complete reference ties, $t(27) = 2.55$, $p < 0.05$, $d = 0.88.$, complete conjunctives, $t(29) = 4.77$, $p < 0.001$, $d = 1.66$, and made more errors of reference, $t(15) = 3.38$, $p < 0.01$, $d = 0.78$ and errors of conjunction, $t(29) = 3.22$, $p < 0.01$, $d = 1.13$ than controls. Stroke patients did

Table 2
Cohesion measures of connected speech: Means and standard deviations for all, left and right hemisphere stroke and healthy controls.

	Group							
	Controls		Stroke					
	(n = 19)		All (n = 18)		Left (n = 6)		Right (n = 8)	
Measure	M	SD	M	SD	M	SD	M	SD
Total number of utterances	277.0	45.1	257.8	64.9	216.5	61.5	297.0	55.4
Complete reference (%)	7.3	2.7	5.4*	1.4	5.4	1.5	5.3	1.0
Reference errors (%)	0.4	0.6	1.8**	1.4	1.8	1.3	2.6**	1.2
Complete conjunctions (%)	6.3	1.1	3.8***	1.8	4.0	2.4	4.2**	0.9
Conjunction errors (%)	1.7	1.0	3.2**	1.6	3.5*	1.8	3.4**	1.1
Complete lexical (%)	6.9	2.8	4.6	2.8	4.9	3.9	5.1	0.7
Complete cohesive ties (%)	13.4	2.2	9.2***	2.5	9.4	3.1	9.4*	1.4
Cohesive errors (%)	2.2	1.3	5.0**	2.6	5.3*	2.5	6.1**	2.2

Note. n = 18 for controls, n = 13 for stroke group, n = 5 for right stroke group. Significant difference from controls following Bonferroni correction, $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$. NB: For subgroup comparisons (i.e. left and right stroke vs. controls), a closely matched smaller control group was used (n = 8; see Section 2).

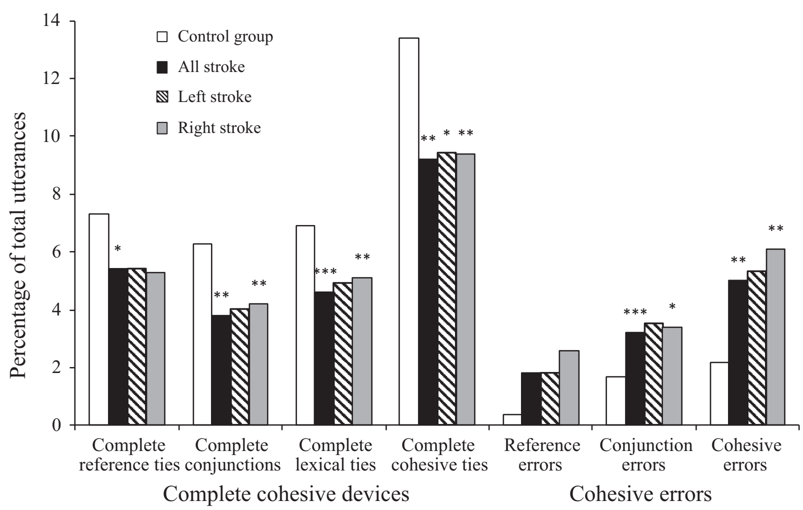

Fig. 2. Means (expressed as a percentage of total utterances) for all measures of cohesion in connected speech, for stroke patients and healthy controls. Significant difference from controls following Bonferroni correction, *p < 0.05; **p < 0.01; ***p < 0.001.

not differ significantly from controls on the number of complete lexical ties, $t(29) = 2.32$, $p > 0.01$, $d = 0.84$.

Subgroup analyses ($N = 18$) confirmed a significant effect of group for total cohesive errors, $F(2,15) = 7.15$, $p < 0.01$, $\eta_p^2 = 0.49$, and errors of conjunction, $F(2,15) = 5.71$, $p < 0.05$, $\eta_p^2 = 0.43$; however, the effect of group on complete cohesive ties, complete conjunctions, reference ties and errors of reference was non-significant ($F(2,15) = 3.97$, $p > 0.01$, $\eta_p^2 = 0.35$; χ^2 (2, $N = 18$) = 6.67, $p > 0.01$; $F(2,15) = 0.60$, $p > 0.05$, $\eta_p^2 = 0.07$; $F(2,15) = 4.77$, $p > 0.01$, $\eta_p^2 = 0.39$, respectively). *T*-tests revealed that both the RHS and LHS groups made a greater number of cohesive errors than controls (RH: $t(10) = 4.11$, $p < 0.01$, $d = 2.28$; LH: $t(11) = 3.05$, $p < 0.05$, $d = 1.64$) and conjunction errors (RH: $t(10) = 3.83$, $p < 0.01$, $d = 2.16$; LH: $t(11) = 2.87$, $p < 0.05$, $d = 1.54$). Furthermore, the RHS group used fewer cohesive ties and complete conjunctions, and made significantly more reference errors than controls ($t(10) = 2.71$, $p < 0.05$, $d = 1.62$; $t(10) = 3.29$, $p < 0.01$, $d = 1.99$; $t(10) = 3.62$, $p < 0.01$, $d = 2.01$, respectively).

3.2.2. Coherence

A summary of coherence connected speech measures is presented in Table 3 (see also Fig. 3). Stroke patients made significantly more local coherence errors, $t(17) = 3.27$, $p < 0.01$, $d = 1.24$, global coherence errors, $t(16) = 2.79$, $p < 0.05$, $d = 1.06$, and propositional repetitions, $t(16) = 3.71$, $p < 0.01$, $d = 1.42$, compared to healthy controls, in line with predictions. By contrast, the percentage of tangential sentences, conceptual congruence errors, and filler sentences did not differ between the stroke group and controls ($t(29) = 0.70$, $p > 0.05$, $d = 0.25$; $t(12) = 1.00$, $p > 0.05$, $d = 0.38$; $t(29) = 1.29$, $p > 0.05$, $d = 0.44$, respectively). Bonferroni adjustments were applied to the four measures of global coherence (propositional repetitions, tangential sentences, conceptual incongruence and filler sentences).

Subgroup analysis confirmed a significant effect of group on local coherence errors, $F(2,15) = 5.75$, $p < 0.05$, $\eta_p^2 = 0.43$, and global coherence errors, χ^2 (2, $N = 18$) = 7.24, $p < 0.05$. *T*-tests revealed that the RHS and LHS groups produced more local coherence errors than controls (RH: $t(10) = 3.48$, $p < 0.01$, $d = 1.89$; LH: $t(11) = 2.72$, $p < 0.05$, $d = 1.47$). Only the RHS group made significantly more global coherence errors than controls (RH: $U = 3.00$, $p < 0.05$; LH: $U = 7.00$, $p > 0.05$). The ANOVA for propositional repetitions was not significant following Bonferroni correction, χ^2 (2, $N = 18$) = 8.59, $p > 0.01$; however, the LHS made significantly more propositional repetitions than the controls, $t(11) = 4.44$, $p < 0.01$, $d = 2.41$.

3.3. Associations between connected speech and attention and executive functions

3.3.1. Attention and executive functions

A summary of scores for attention and executive function tasks is presented in Table 1. All attention task analyses were Bonferroni corrected for two variables: sustained and selective attention.

Table 3
Coherence measures of connected speech: means and standard deviations for all, left and right hemisphere stroke and healthy controls.

	Group							
	Controls		Stroke					
	($n = 19$)		All ($n = 18$)		Left ($n = 6$)		Right ($n = 8$)	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Total number of utterances	277.0	45.1	257.8	64.9	216.5	61.5	297.0	55.4
Local coherence errors (%)	4.3	6.4	16.6**	12.4	17.1*	10.3	22.6**	12.1
Global coherence errors (%)	4.1	4.9	12.5*	10.1	7.7	3.3	14.0*	9.4
Tangential sentences (%)	0.2	0.7	0.4	0.9	0.0	0.0	1.0	1.3
Conceptual incongruence (%)	0.0	0.0	0.2	0.7	0.0	0.0	0.5	1.1
Propositional repetitions (%)	2.1	2.3	7.3**	4.6	6.3**	2.7	8.8	7.1
Filler sentences (%)	1.8	3.7	4.7	8.5	1.4	1.6	3.8	4.8

Note. $n = 18$ for controls, $n = 13$ for stroke group, $n = 5$ for right stroke group. Significant difference from controls following Bonferroni correction, $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$. NB: For subgroup comparisons (i.e. left and right stroke vs. controls), a closely matched smaller control group was used ($n = 8$; see Section 2).

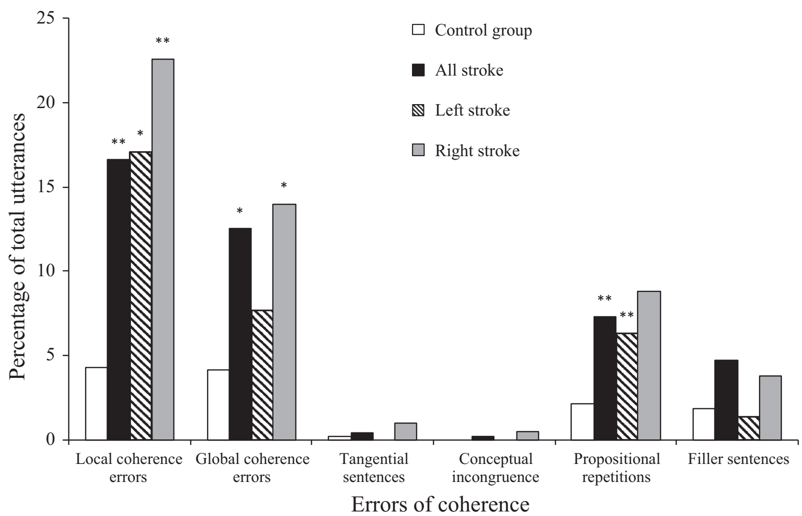

Fig. 3. Means (expressed as a percentage of total utterances) for all measures of coherence in connected speech, for stroke patients and healthy controls. Significant difference from controls following Bonferroni correction, $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

There was no difference between the stroke and control groups on the Elevator Counting task (sustained attention), $t(23) = 2.28$, $p > 0.01$, $d = 0.75$). Notably, 10 of 18 Stroke patients performed below the clinical cut off for the Elevator Counting test, in contrast to only 3 of 21 controls; therefore we included this measure in the correlation analyses that follow. Stroke patients performed significantly worse than healthy controls on the Elevator Counting with Distraction task (selective attention), $t(37) = 2.38$, $p < 0.05$, $d = 0.76$. Although the subgroup ANOVA was not significant, $F(2,19) = 4.06$, $p > 0.01$, $\eta^2_p = 0.30$, *t*-tests revealed that the RHS group performed significantly worse than controls on this task, $t(14) = 2.53$, $p < 0.05$, $d = 1.27$.

The stroke group as a whole performed significantly below the control group on the Hayling Sentence Completion Test Overall Scaled Score (SS), $t(36) = 3.33$, $p < 0.01$, $d = 1.09$, Suppression RT SS, $t(36) = 3.03$, $p < 0.01$, $d = 0.99$, and Suppression Error SS, $t(36) = 3.03$, $p < 0.01$, $d = 0.98$, though there was no significant difference between the stroke and control groups on the Initiation RT SS, $t(36) = 2.39$, $p > 0.01$, $d = 0.75$. All Hayling comparisons were Bonferroni corrected for four variables. There was no main effect of group for Hayling Sentence Completion Test scores at the subgroup level (Overall SS: $F(2,18) = 1.70$, $p > 0.05$, $\eta^2_p = 0.16$; Suppression RT SS: $F(2,18) = 1.01$, $p > 0.05$, $\eta^2_p = 0.10$; Suppression Error SS: $F(2,18) = 1.55$, $p > 0.05$, $\eta^2_p = 0.15$; Initiation RT SS: $F(2,18) = 5.05$, $p > 0.01$, $\eta^2_p = 0.36$). Only the Overall and Suppression Error scaled scores were used in the correlational analyses, as suppression errors were of particular interest, given the potential role of the supervisory attention/executive processes of inhibition and "monitoring" (e.g. Hornberger & Bertoux, 2015).

3.3.2. Cohesion

Neither sustained nor selective attention was significantly correlated with any measures of cohesion in the whole stroke group (all $p > 0.05$). However, performance on the Elevator Counting with Distraction task (selective attention) was positively associated with complete use of conjunctions in the RHS group, $rho = 0.90$, $p < 0.05$. The Elevator Counting task (sustained attention) was not significantly correlated with any measure of cohesion for the whole stroke group or RHS group (all $p > 0.05$).

Cohesion was not significantly associated with either of the Hayling measures in the whole stroke or LHS groups. However, in the RHS group, better Hayling Overall performance and fewer suppression errors were both associated with greater use of correct conjunctions, $rho = 0.90$, $p < 0.05$, and $rho = 0.98$, $p < 0.01$. Furthermore, better Hayling Overall performance was related to higher use of complete reference ties, $rho = 0.90$, $p < 0.05$.

3.3.3. Coherence

For the whole stroke group, performance on the Elevator Counting task (sustained attention) and the Elevator Counting with Distraction task (selective attention) was significantly negatively correlated with propositional repetitions, $rho = -0.69$, $p < 0.01$, and $rho = -0.65$, $p < 0.05$, respectively. Furthermore, better performance on the Elevator Counting with Distraction task (selective attention) was associated with fewer global coherence errors, $rho = -0.62$, $p < 0.05$. In the RHS group, poorer performance on the Elevator Counting task (sustained attention) was associated with increased propositional repetitions, indicating that increased sustained attention is associated with fewer propositional repetitions, $rho = -0.98$, $p < 0.01$.

In the whole stroke group, better performance on the Hayling Sentence Completion Test (Overall Scaled Score) was correlated with fewer errors of global coherence and propositional repetitions, $rho = -0.76$, $p < 0.01$, and $rho = -0.77$, $p < 0.01$, respectively. Furthermore, increased Hayling suppression errors was associated with a higher number of global coherence errors and propositional repetitions, $rho = -0.62$, $p < 0.05$, and $rho = -0.57$, $p = <0.05$. In the LHS group, better Hayling Overall performance was again associated with lower global coherence errors and propositional repetitions, $rho = -0.94$, $p < 0.01$ and $rho = -0.88$, $p < 0.05$. In the RHS group, poorer Hayling Overall performance and increased suppression errors were associated with a higher number of propositional repetitions, $rho = -1.0$, $p < 0.001$ and $rho = -0.98$, $p < 0.01$. In the context of small patient numbers, we are cautious about these findings; however, they are strongly suggestive of an association between coherent, cohesive connected speech and attention/executive functions that warrants further investigation.

4. Discussion

This is the first known study to use a detailed multi-level analysis of connected speech to examine cohesion and coherence in a heterogeneous non-aphasic stroke population, with the goal of elucidating the role of attention and executive functions during the conceptual preparation of a message. The stroke patients, who had relatively mild cognitive deficits, were well matched to healthy controls. Although the stroke group performed below controls on tests of naming and word comprehension, closer inspection revealed that only one right hemisphere stroke patient was clinically impaired based on normative data (i.e., <5th percentile cut-off) in both nominal and word comprehension skills. This may indicate crossed aphasia, which occurs when language centres are not localised to the left hemisphere in right-handed individuals; thus a right hemisphere stroke may result in symptoms of aphasia (Heilman & Valenstein, 2003). Although spontaneous speech as elicited from complex scene description (Cookie Theft Scene) was significantly reduced in stroke patients compared to controls, it is worth noting that this productivity reduction is mild and not indicative of non-fluent aphasia. Our stroke group produced more than double the words per minute of patients with non-fluent aphasia (Berndt, Wayland, Rochon, Saffran, & Schwartz, 2000), and four times that of patients with dynamic aphasia (see Robinson, Spooner et al., 2015). Thus, apart from a mild reduction in the productivity of spontaneous speech, core language abilities were largely preserved and cannot entirely account for connected speech impairments. With regard to the cognitive baseline, while the stroke group as a whole did not perform worse than the control group on the Advanced Progressive Matrices, the RHS group did perform below controls. Additionally the LHS group performed below controls on phonemic word fluency. The Matrices and phonemic word fluency tasks tend to draw on processes associated with the frontal lobes (Duncan, Burgess, & Emslie, 1995; Henry & Crawford, 2004).

For the first time, we have demonstrated impairments in the conceptual processes of cohesion and coherence in mild stroke. As expected, stroke patients performed significantly below controls on measures of cohesion and coherence in connected speech, and this was particularly apparent for the right stroke group. Moreover, performance of the stroke group on the selective attention task (Elevator Counting with Distraction) was significantly impaired relative to controls, and subgroup analysis revealed that the RHS group performed significantly below controls. Notably, inspection of the raw scores revealed that the RHS group had largely impaired selective attention relative to the LHS group, as 5 of the 8 RHS patients performed below the 5th percentile on this task, while only 1 LHS patient did. Our analyses did not show a significant difference between the stroke and control groups on our sustained attention task (Elevator Counting); however, this task has a low ceiling and therefore lacks sensitivity. In the TEA manual, Robertson, Ward, Ridgeway, and Nimmo-Smith (1994) highlight that "even a single error (on this task) may very likely be significant, and two errors is very definitely indicative of a problem of sustained attention" (p. 15). Raw scores showed that 10 of the 18 Stroke patients made one or more error. Importantly, no LHS patient made more than one error, but impaired RHS patients made an average of two errors, indicating greater sustained attention impairments in the RHS group. This is consistent with previous studies in stroke (e.g., Hyndman & Ashburn, 2003; Jokinen et al., 2006; Nys et al., 2005). Furthermore, the stroke group performed significantly below controls on all Hayling Sentence Completion Test scaled scores, except for the Initiation RT section. Despite small numbers, our results are strongly suggestive of a relationship between attention/executive functioning and coherent speech.

4.1. Connected speech in stroke

4.1.1. Cohesion

Overall, stroke patients used fewer complete cohesive ties and made more cohesive errors, and were particularly impaired in use of reference, compared to controls. Reference ties direct the listener to the identity of the subject/object to which they refer (Halliday & Hasan, 1976). In narrative production, a speaker is often required to discriminate between characters in a story using personal pronouns. Indeed, inspection of the error types revealed that personal pronouns (e.g., he, she, they) were the most common type of reference attempted and erroneously used by stroke patients. Stroke patients also showed impaired use of conjunctions. Inspection of the errors revealed that the majority were due to excessive use of the conjunctive "and". Sherratt and Bryan (2012) suggest the principal use of "and" is as a "continuant or placeholder…or may also indicate that the speaker had difficulty in providing a conjunction to reflect the relationship between the propositions, thus rendering the relationship unclear" (p. 19) (see Appendix B).

Both RHS patients and LHS made more conjunction errors and more cohesive errors overall than controls, consistent with previous studies (e.g., RHS - Marini et al., 2005; LHS - Marini et al., 2007). However, inspection of the means suggests a trend towards a greater cohesion impairment in RHS patients, as they made notably more reference, conjunctive and cohesive errors relative to LHS patients, and used fewer cohesive ties and correct conjunctions (see Table 2). Unfortunately, a primary limitation of the current study was small numbers and heterogeneous groups, which precludes unequivocal conclusions about laterality.

4.1.2. Coherence

As predicted, stroke patients were impaired in global coherence, suggesting deficits in the ability to adequately maintain the topic of narrative speech. Notably, stroke patients produced a large number of propositional repetitions, suggesting that their global coherence deficit may be underpinned by a more generalised tendency to insert repetitive comments into their narratives, highlighting difficulties in producing novel conceptual information (see also Law et al., 2015). Perhaps of relevance here is that increased propositional repetitions and tangential sentences in connected speech were related to poorer word comprehension skills (Language Baseline: Synonym Test). The synonym task taps semantic knowledge; therefore, repetitive or tangential speech may indicate a paucity of ideas, the formulation of which draws on semantic knowledge, or poor semantic control during the selection of an idea from multiple semantically-related activations (for a similar view see Noonan, Jefferies, Corbett, & Ralph, 2010). Increased propositional repetitions may also represent difficulties with attention and suppression of unwanted or previously primed responses (e.g., Cohen & Dehaene, 1998; Goldstein, 1939; Plaut & Shallice, 1993). Indeed, poorer performance on attention measures and increased Hayling suppression errors were correlated with the number of propositional repetitions in the stroke group. Propositional repetitions have been suggested to reflect a strategy to cope with word finding difficulties (Christiansen, 1995; Davis et al., 1997; Marini, 2012). However, this is unlikely for our stroke patients as they showed relatively mild nominal impairments and nominal skills were not correlated with the number of propositional repetitions. Although only the LHS group made significantly more propositional repetitions than controls, close inspection of the data reveals that three patients from the LHS group and three from the RHS group were impaired and performed more than two standard deviations above the mean of the control group on this measure.

As predicted, stroke patients produced a higher number of local coherence errors than controls. Inspection of the errors suggests that impaired performance was largely due to missing or erroneous use of reference, as opposed to abrupt topic shifts. This is consistent with our finding that use of reference is impaired following stroke; it is likely that this contributes to impaired local coherence.

RHS patients were impaired in local and global coherence, consistent with previous studies (e.g., Bartels-Tobin & Hinckley, 2005; Marini, 2012; Sherratt & Bryan, 2012). Interestingly, our repetitive utterance pattern of impairment was qualitatively different than that of Marini (2012), who found that patients with right hemisphere damage produced more tangential and conceptually incongruent, rather than repetitive, utterances. This led Marini (2012) to speculate that coherence impairments resulted from an inability to process relevant conceptual information. In contrast, our findings support Sherratt and Bryan (2012) who described a significant number of fluency and content disruptors (i.e., repeated words phrases or ideas/comments on the task, semantic perseveration) in the personal narratives of patients with right brain damage. Sherratt and Bryan suggest that this might reflect an impairment in selecting relevant and appropriate information, at the level of *selection* and *topicalisation* of information, and that repetitive utterances might represent a strategy to provide more processing time while they prioritise information and select the syntactic structure for expression (Sherratt & Bryan, 2012). As previously reported, LHS patients were also impaired in local coherence (Bloom, Borod, Obler, Santschi-Haywood, & Pick, 1996; Christiansen, 1995).

Comparisons between patients with right and left hemisphere lesions showed cohesion and local and global coherence were mediated by bilateral networks. However, close inspection of the data reveals a possible right hemisphere laterality effect for coherence deficits. Only the RHS group made significantly more global coherence errors than controls, and made almost double the errors of the LHS group, and Table 3 shows that although both RHS and LHS groups are impaired in local coherence relative to controls, the RHS group made more than five times the number of errors as controls, while the LHS group made only four times the errors of controls.

4.2. Attention and executive function in connected speech

Our findings provide preliminary evidence for the role of executive function, alongside two attention processes, in connected speech. The Hayling Sentence Completion Test yields an overall scaled score, which is derived from the three sub-scale scores (response initiation, response suppression and suppression errors). Therefore, the Hayling Overall Scaled Score reflects total performance and the executive mechanisms of initiation and inhibition. We found that Hayling Overall performance was associated with the production of coherent speech in the whole stroke, RHS and LHS groups. Our results are in line with recent conceptualisations of executive functions, which propose that they are diverse cognitive skills which integrate, organise, maintain and control behaviour through a system of attentional control processes that have the potential to affect all realms of cognitive processing including language (Stuss & Alexander, 2007). Coherence, at a global level, reflects the degree to which propositions are organised with respect to the overall goal of the speech; the production of coherent speech is a goal-directed behaviour requiring all elements of executive function. Attention can be considered as one component process that subserves executive function, and as our results suggest a link between executive function and coherent connected speech production, attention may play a particular role.

We found that decreased selective attention was related to the production of coherent speech (i.e. a higher number of propositional repetitions and global coherence errors) in stroke patients. The ability to selectively attend may be important for topic maintenance as the speaker must allocate their attention to a current focus in the face of competing alternatives. In this context, selective attention relies more heavily on goal-directed top-down selection processes, rather than a stimulus-driven bottom-up attention process (e.g., Corbetta & Shulman, 2002). Furthermore, selective attention involves working memory processes (e.g., Baddeley, 1996), which may be important for producing cohesive speech. In the RHS group, selective attention was associated with the use of conjunctions. The speaker must be able to hold the previous utterance in mind, and select the appropriate cohesive device, in order to express the required relationship between utterances. Hence, selective attention may be recruited to help maintain meaning across sentences through the selection of conjunctions. In this context, we can speculate that selective attention may be an "on-line" stimulus-driven process that demands monitoring (a top-down process). Monitoring is one of Stuss and Alexander's (2007) three supervisory attention processes that underpin executive function, and is often attributed to the right lateral prefrontal cortex (Shallice, Stuss, Alexander, Picton, & Derkzen, 2008; Stuss, 2011; Vallesi, 2012). Interestingly, the right stroke group performed well below the left stroke group on the selective attention test, and as previously noted, our results suggest a potentially greater cohesion impairment in RHS patients. If the production of cohesive speech requires selective attention as an "on-line" process that demands monitoring, then right frontal function may play a critical role. Furthermore, two RHS patients produced the highest number of propositional repetitions. It is likely that monitoring plays a role here too, as avoiding propositional repetitions in speech relies on the ability to monitor output over time.

Recently, the right lateral frontal region was implicated in verbal response suppression on the Hayling Sentence Completion Test (Robinson, Cipolotti et al., 2015). Patients with focal right lateral lesions showed a high rate of suppression errors that was not attributed to faulty monitoring per se as these patients also failed to generate and/or implement a strategy. However, in a commentary on this study, Hornberger and Bertoux (2015) suggested that failing to monitor task goals in the Hayling test might result is a subsequent failure to implement and maintain a strategy across trials, leading to increased suppression errors. Thus, the possibility of monitoring as an attention process critical in language production is highlighted in patients with right frontal damage. In the current study, increased suppression errors on the Hayling task was related to more propositional repetitions (a coherence measure) and reduced use of correct conjunctions (a cohesion measure) in the RHS group. If, as Hornberger and Bertoux (2015) argue, a failure of monitoring is driving an increase in suppression errors, it is possible that this same faulty monitoring mechanism might underpin these cohesion/coherence errors in the RHS patients.

Finally, we found that sustained attention was also important for production of a coherent narrative in the whole stroke group and the RHS group. Connected speech production involves a temporal component where ideas are conveyed over time, requiring attention to be sustained on both the discourse focus, and the ongoing monitoring/ evaluation of the state of communicative context (Alexander, 2006; Levelt, 1999; Sherratt & Bryan, 2012). The production of coherence errors, particularly propositional repetitions, may be interpreted as lapses in sustained attention to the discourse focus over time, which is manifested as repetitive content. Furthermore, the production of propositional repetitions may be interpreted as reflecting a deficit in the *fluent sequencing of novel thoughts* (Robinson et al., 2006). Recent evidence from two patients (MC, WAL) with dynamic aphasia suggests that the ability to generate novel thoughts, and the ability to sequence these thoughts, comprise two distinct components of this conceptual preparation mechanism (Robinson, 2013; Robinson, Spooner et al., 2015). In order to convey ideas over time, the speaker must be able to sequence, or order, their thoughts. Deficits in fluent sequencing may be evidenced by perseverative responses (Robinson, 2013), or, as in the current study, propositional repetitions in connected speech. However, as previously noted, reduced sensitivity of the Elevator Counting task in capturing sustained attention deficits may have masked significant effects. Future studies could include alternative tasks that are more sensitive to sustained attention deficits, such as the Lottery task from the TEA (Robertson et al., 1996).

As attention is a finite resource, we can speculate that the production of cohesive and coherent speech requires a balance of top-down and bottom-up processes, and that an imbalance may manifest as deficits in coherence or cohesion. Broadly, executive function and attention correlated with some but not all connected speech measures. Thus, these preliminary results should be considered cautiously. We also note that correlational analyses may indicate the strength and direction of a relationship, but not causation.

4.3. Implications

The coherence and cohesion impairments evident in stroke patients' connected speech can be interpreted as a deficit in conceptual preparation mechanisms. Our results hint at a key role of attention/executive functions, lending particular support to the theoretical notion that sustained attention or *discourse focus*, and the ability to allocate attention to a *current focus* (selective attention), are important for conceptual preparation of a message (Levelt, 1999, p. 90). Sustained and selective attention, as well as Hayling suppression errors, were associated with an increase in repetitive speech and reduced global coherence. This suggests that reductions in attention, and impairments in executive mechanisms such as inhibition, may mediate these difficulties following stroke, even when overall cognitive deficits were mild (as detailed in Law et al., 2015).

Our findings also have implications for the literature on dynamic aphasia, which has hinted at the role of attention and executive function in propositional language impairments (e.g., Bormann, Wallesch, & Blanken, 2008; Robinson, 2013; Robinson, Spooner et al., 2015; Robinson et al., 2006). Specifically, impaired ability to produce fluent propositional speech has been interpreted as a deficit in focussing or selectively attending to a current message to be expressed (patient KAS - Robinson et al., 2006) and perseverative speech was suggested to reflect a fluent sequencing deficit, as distinct from a novel thought generation deficit per se (patient MC - Robinson, 2013), with a pure novel thought generation deficit comparable to an energization deficit (patient WAL – Robinson, Spooner et al., 2015). In our stroke group (without dynamic aphasia), reductions in selective attention were significantly correlated with propositional repetitions. These results provide preliminary evidence that impaired attention and supervisory executive processes may be important cognitive mechanisms underlying propositional language deficits, though it is likely that other attentional control processes (e.g., energization, task-setting, and attentional switching) play a role as well.

The current study underscores the importance of focussed cognitive and language assessments in ascertaining the source of difficulty in connected speech. This may eventually inform treatment planning and evaluation. Although connected speech assessments employing this approach are time consuming, they would permit treatment to be focussed on the specific deficits, obviating the need for time and resources to be spent on remediating preserved aspects (Sherratt & Bryan, 2012). This would allow treatment approaches to be tailored; for example, a top-down approach that stimulates cognitive functions, such as attention, could be used to treat cohesion and coherence impairments (Rogalski et al., 2010). Identification of the most efficient avenue of treatment for specific deficits is needed, for example, whether to target the actual discourse deficits (e.g., cohesion/coherence) or potential underlying factors (e.g., attention/memory) (Coelho, 2005). For instance, Novakovic-Agopian et al. (2011) detail a goals training intervention program with acquired brain injury patients. This program places particular focus on attention training alongside Goal Management Training, mindfulness and problem solving, with the objective of linking attentional regulation to goal-attainment behaviour. The authors discuss attentional control as a "'gateway' function that could influence the efficiency and effectiveness of other executive functions" (p. 2). Patients improved on various neuropsychological measures of complex attention and executive functions. It is still a leap to expect attention training to smoothly transition to the treatment of discourse deficits, but when connected speech is considered as another goal-directed behaviour, the possibility of attention training forming part of language rehabilitation programs seems feasible for the future.

4.4. General conclusion

The ability to produce connected speech is fundamental to daily communicative functioning, and involves important conceptual processes, such as the ability to organise ideas into a cohesive and coherent representation. Our results are the first to indicate that impairments in cohesion and coherence can occur following stroke, without the presence of prominent aphasia. Furthermore, our study highlights the role of executive functions and attention in connected speech.

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Table A1
Background details for stroke patients.

Patient	Sex	Age	Handedness	Education[a]	Chronicity[b]	LH/RH	Clinical neuroimaging summary[#]
1	F	76	R	15	193	LH	Left fronto-parietal + basal ganglia
2	M	54	R	15	334	LH	Left fronto-parietal (CT)
3	F	54	L	16	202	LH	Left parietal + basal ganglia
4	M	64	R	16	343	LH	Left thalamus
5	M	84	R	9	124	LH	Left thalamus + Left temporo-occipital (CT)
6	F	67	R	12	494	LH	Left thalamus + occipital + cerebellar
7	F	78	R	18	326	–	Bilateral WM lesions + small Left posterior frontal
8	M	54	R	23	209	–	Bilateral WM lesions + small Left pons
9	M	78	R	10	44	–	Left posterior frontal + old Right occipital
10	M	79	R	14	95	–	Right frontal + old Left cerebellar
11	F	60	R	15	212	RH	Right frontal + temporal + basal ganglia (CT)
12	F	47	R	10	445	RH	Right thalamus + temporal + basal ganglia (CT)
13	M	65	R	13	205	RH	Right temporo-parietal
14	M	64	R	10	684	RH	Right fronto-tempro-parietal + basal ganglia (CT)
15	M	73	R	10	249	RH	Right parietal + basal ganglia (CT)
16	M	68	R	12	497	RH	Right temporo-occipital + bilateral WM lesions
17	F	66	R	11	371	RH	Right parieto-occipital + bilateral WM lesions
18	M	53	R	10	94	RH	Right pons

Note. F = Female; M = Male; L/R = left-handed/right-handed, LH/RH = Left/Right Hemisphere Stroke Group; – = no Stroke subgroup; # = aetiology is infarction for all cases; imaging type is Magnetic Resonance Imaging (MRI) except where CT (Computerised Tomography) is indicated.
[a] Education in years.
[b] Chronicity (time since stroke) in days.

Table B1
Definitions and examples of the categories of cohesive ties from Halliday and Hasan (1976).

Type	Subtypes	Examples
Reference		
An item which cannot be interpreted semantically in its own right, but makes reference to preceding speech for its interpretation.	*Personal reference* is the use of personal pronouns and determiners such as he, she, his, her, one, we, you, they, it.	Cinderella went to the ball// *she* danced with the prince//
	Demonstrative reference is identification of the referent by locating it on a scale of proximity using determiners such as this/these, that/those, here/there and now/then.	Cinderella lost her glass slipper// and *that* made her sad//
	Comparative reference is identification of the referent as one of sameness, similarity or dissimilarity. It is concerned with comparison of quality and quantity.	Cinderella helped her sisters clean// but they were not quite *as nice*//
Conjunction		
An item that specified the way in which the utterance following it was connected to what had gone before.	*Additive conjunctions* aim to add new examples or make a restatement to support a previous argument and include 'and, for instance, nor, or, furthermore, likewise'.	A pumpkin was turned into a coach//*and* the mice into white horses//
	Adversative conjunctions contrast two arguments or bring attention to another important message and include 'yet, but, however, in fact, on the other hand, instead, rather, anyhow, in any case'.	The fairy godmother said Cinderella could go to the ball// *but* she would have to be home by midnight//
	Causal conjunctions signify a cause-effect relationship and include 'so, consequently, as a result, because, it follows, otherwise, in this respect'.	The ugly stepsisters were furious// *so* they tried to hurt Cinderella//
	Temporal conjunctions link two arguments in a time sequence and may signal change and include 'then, previously, at once, meanwhile, next, first…then, finally, from now on, to sum up, briefly'.	First Cinderella washed the dishes// *then* she swept the floor//
Lexical		
The repetition of various forms of lexical items through repetition, replacement, or use of a synonym, near-synonym, or a superordinate name.		Cinderella lost her glass slipper// but she was too upset to care about the shoe//

Appendix A

See Table A1.

Appendix B

See Table B1.

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