Conceptualisation difficulties in stroke-induced and primary progressive aphasia

Inga Hameister

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Department of Cognitive Science

Faculty of Human Sciences

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Declaration

I, Inga Hameister, certify that the content in this thesis entitled “Conceptualisation difficulties in stroke-induced and primary progressive aphasia” has not been previously submitted for a higher degree to any other institution or University. All the work reported in this thesis was undertaken during the time I was enrolled as PhD student at Macquarie University under the supervision of Prof Lyndsey Nickels and Prof Roelien Bastiaanse (University of Groningen, Netherlands).

I also certify that this thesis is an original piece of research and it has been written by me. Any help and assistance that I have received in my work, and the preparation of the thesis has been appropriately acknowledged. Furthermore, all information sources and literature that have contributed to the thesis have been acknowledged throughout the thesis.

The research presented in this thesis was approved by the Macquarie University Human Ethics Review Committee, reference number: 5201200905. This was also ratified by the Ethics Committee of the University of Groningen (Netherlands), reference number: 45061539 and the Ethics Committee of the Medical Faculty of the Rheinisch-Westfälische Technische Hochschule (RWTH) in Aachen (Germany), reference number: EK 228/17

Signed:

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General Summary

In order to speak we have to transform our thinking into a form that can be verbally expressed – so called *conceptualisation*. Conceptualisation processes, including the selection and ordering of important information, perspective taking and topic maintenance, can be particularly difficult for individuals with acquired language impairments.

This thesis aimed to identify symptoms of conceptualisation deficits in people with neurological language impairments (stroke aphasia, Primary Progressive Aphasia [PPA]) using a speech production task that is commonly used in clinical assessment (i.e., picture description)

This research applied a modification of an established connected speech analysis - concept analysis - to investigate the number, quality and order of the information produced in picture description.

The results showed that some individuals with stroke-aphasia (**Chapter 2**) and PPA (**Chapter 3**) omitted essential information and/or showed difficulties producing it in an appropriate temporal order. These impairments were hypothesised to be associated with either linguistic or cognitive impairments (e.g., working memory, attention).

Chapter 4 investigated how far discourse macrostructure was influenced by impaired word availability. The 'Taboo paradigm' was used to induce lexical access difficulties in unimpaired speakers and their performance compared to speakers with aphasia. The results suggested that impaired word availability can account for a reduced amount of essential information. However, omissions of the most central concepts and temporal order violations, observed in some speakers with aphasia, cannot be explained by linguistic impairment alone.

Chapter 5 reports a pilot investigation of the eye movements made during complex picture description. This pioneering study revealed clearly different gaze patterns (e.g., timing of fixations to critical areas) between a man with aphasia and unimpaired controls. This motivates the use of eye tracking for further research on conceptualisation difficulties.

In summary, the results of this thesis provide evidence for the possible symptoms of conceptualisation difficulties in individuals with stroke-induced and primary progressive

aphasia and have clinical application for enhancing the effectiveness of aphasia diagnosis and treatment

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CHAPTER 1

General Introduction

"It is there in my head, but … I don't get the words out"

(George, 47, stroke-induced aphasia 14 months post onset)

Many people who experience some degree of language impairment after a stroke, a traumatic brain injury or in the progress of a neurodegenerative disease feel like George. As a clinician, I was particularly intrigued by statements like this. How is it possible that a person's internal representation of language, while preparing what to say, seems unimpaired when he/she shows profound difficulties in actually producing the message?

A few months after George, I met Sarah who also experienced symptoms of aphasia following a stroke. When I asked Sarah to describe a few simple pictures, for example of *a man mowing the lawn*, she mentioned the pebbles in the wall in the background, the colour of the lawn mower (red) and the clothes of the man (short pants). However, she did not mention any of the critical elements of the picture (*man*, *lawn, or mowing*) neither did she attempt to communicate any of these entities non-verbally (e.g., by pointing). In contrast to George, Sarah did not seem to have the readily prepared message in her "head". On the contrary, it appeared like she struggled to identify which part of the picture is important and needs to be communicated and which aspects can be neglected.

These experiences with George and Sarah sparked the main research questions for this dissertation: *Is it possible that the language impairments of some individuals with aphasia are underpinned by broader speech planning (conceptualisation) difficulties? What symptoms would indicate such an underlying conceptualisation impairment?* and *How can we best diagnose it?*

Conceptualisation - From thought to language

For decades researchers have aimed to understand more about how we organise our internal thoughts to create and/ or express new ideas about the world - hereafter referred to as conceptualisation (Chafe, 1990). Defining a process that cannot be directly observed is a difficult task; consequently, the literature has about as many different interpretations of the term 'conceptualisation' as there are researchers in the field (Nuyts & Pederson, 1997).

In more general terms, conceptualisation can be understood as a process in which we schematise abstract thoughts, emotions or sensory experiences and combine them to create more specific idea (Chafe, 1990; Langacker, 1986). However, there is a debate about how exactly this schematisation takes place (Nuyts & Pederson, 1997).

One of the most commonly reported views is that conceptualisation is organised in sentence-like units that can be described as a kind of internal '*language of thought*' (Fodor, 1975, 2008). Fodor proposed that each mental representation has a specific role, therefore, they cannot be arbitrarily combined in the thinking process and must be organised by a set of internal rules that result in a form of mental sentence (Fodor, 1975, 2008).

Importantly, the only way to gain insights into conceptualisation processes is to study it indirectly, by analysing different types of behaviour guided by conceptualisation. Since language represents our thoughts in a highly schematised form, it is the most commonly studied behaviour in this field (Fodor, 2008; Nuyts & Pederson, 1997).

My thesis aligns with this long stream of research and focusses on conceptualisation as the process that enables us to structure our thinking in a way that we can talk about it (Slobin, 1996).

While there are a number of theories outlining the processes of speech production, the vast majority do not explicitly include preverbal conceptualisation stages. These theories instead either assume that this has already taken place or summarise them within a general semantic level (e.g., Bierwisch & Schreuder, 1992; Dell & O'Seaghdha, 1992; Morton, 1969; Nickels & Howard, 1994). Indeed, Levelt's (1989) speech production model, also known as a "blueprint for the speaker" (Levelt, 1989, p. 9), is one of the only models that describes conceptualisation for speech production in great detail. Levelt summarises the large number of mental activities that are necessary to conceptualise in one processing system called the "Conceptualizer" (see Figure 1; Levelt, 1989, p. 9).

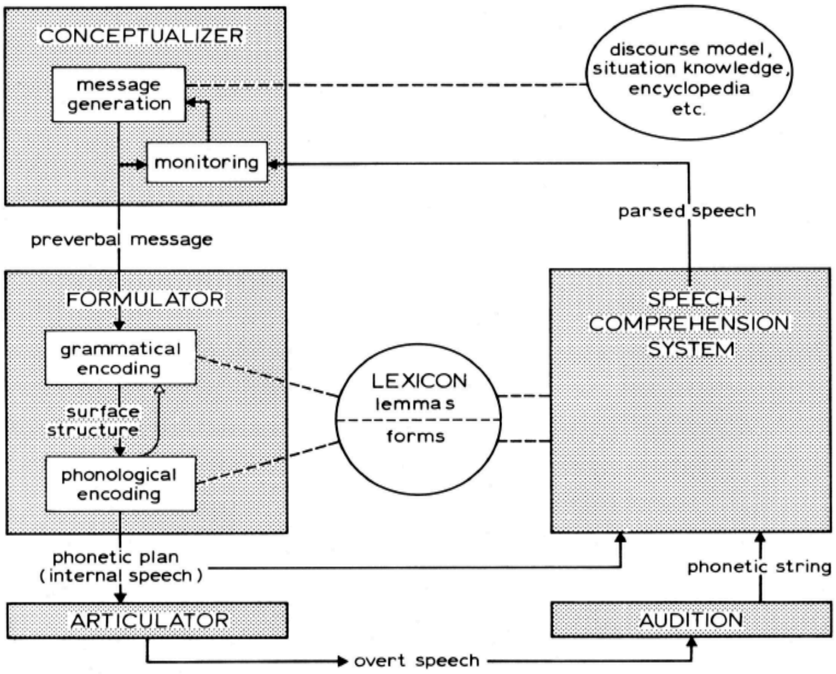

Figure 1: Schematic representation of the speech production model according to Levelt (1989) – reprinted from Levelt (1989, p. 9)

Every communicative act starts with an intention. Typically, the intention of the speaker is to change the current mental model of his/her listener, for example, by providing new information or confirming information the listener already has (Levelt, 1989). To follow this intention, the speaker needs to plan what s/he wants to say by forming a preverbal message. This preverbal message needs to contain all the information the speaker wants to convey in a sentence-like format that can be further processed by the formulator (see Figure 1). As Levelt argues, a "working model […] can hardly account for the complexity of spoken language" (Levelt, 1999, p. 89). Nevertheless, the conceptualisation steps presented in Levelt's model outline important assumptions on how discourse is conceptualised more generally. Therefore, Levelt's model provides the most appropriate theoretical base to investigate the research questions presented in this thesis.

Levelt's speech production model is based on the assumption that discourse is guided by pragmatic aspects (e.g., common knowledge of interlocutors). It is the speaker's goal to move the attention of the listener along with the content and make what he/she says easily accessible and comprehensible. Levelt (1989) argued that conceptualisation is achieved in two steps. The first step, during which the general structure of the preverbal message is generated, is called *macroplanning*.

Macroplanning

Levelt (1998) describes macroplanning as the first major planning step during conceptualisation. Here, the general outline of the discourse is determined. The two main goals of macroplanning are A) the selection of appropriate information that follows the speaking intention and B) the bringing of the individual information units into a sensible order, so that it facilitates the listener's comprehension (Levelt, 1999).

Information Selection

Levelt (1989) argues that in order to select the most appropriate information and ensure successful communication (Cooperation principle; Grice, 1975), the discourse has to follow the basic communication maxims proposed by Grice (1975). First, the speaker needs to be informative without over- or underspecifying the content he/she wants to convey (maxim of quantity). Further, the speaker should only mention information that he/she believes to be true (maxim of quality) and that is relevant to the message (maxim of relation). Lastly, the speaker should avoid any ambiguity and formulate the message as clearly and briefly as possible (maxim of manner). In any conversation the interlocutor expects the speaker to follow these rules. Although flouting any of these rules increases the risk of a misunderstanding or failed communication, the speaker can intentionally violate Grice's maims to convey implicatures (e.g., conveying a message using irony; Grice, 1975). Therefore, flouting of Grice's maxims can be used as a method to communicate and/or emphasise the speaker's point of view.

To achieve successful communication, the speaker must have certain beliefs about the listener's previous knowledge and the amount of knowledge they already share, to select the most appropriate information for a message (Levelt, 1989). For example, a sentence like "The Queen of England is on television." assumes that the listener already knows that England has a queen. The speaker also needs to have "procedural knowledge" (e.g., If A then B; Levelt, 1989, p. 9) about how messages need to be structured.

Overall, the macrostructural process of information selection loads heavily on memory resources (Levelt, 1989; Murray, 2012). Firstly, long term memory is necessary to adequately consider the speaker's as well as the listener's previous world knowledge. Secondly, the speaker needs to rely on working memory to keep the previously retrieved information easily accessible for speech production.

Importantly, in this thesis, I will also refer to *concepts* as units which emerge from the conceptualisation process. I am aware that there are many different definitions of a concept within the literature (Nuyts & Pederson, 1997). Therefore, it is important to outline that in the studies presented in this thesis, I will use the term *concept* when I refer to the information units the participants produce in their discourse (see Chapters 2-5).

Information Sequencing

The second important planning process that Levelt (1989) argues takes place during macroplanning is the adequate sequencing of information to ensure that the listener is able to follow the message conveyed by the speaker.

Here it is important to note that *information sequencing*, as used in this thesis, describes the order of different individual concepts (e.g., "<u>The man went to the bank</u> and <u>got some money</u>" vs. "<u>The man got some money</u> and <u>went to the bank</u>") and does not refer to the ordering of individual constituents within a sentence (e.g., "The bank is open on Saturdays" vs. "On Saturdays the bank is open") (Levelt, 1989).

One way of organising the individual information units in discourse, would be to follow their natural temporal order (principle of natural order, Levelt, 1989). This principle holds for all content that has some kind of chronological order known to the speaker and listener. A natural order of events can mostly be found in expository discourse like descriptions of set procedures (e.g., cooking instructions; Longacre, 1983). In narrative discourse, in which the speaker conveys an experience, individual events often exhibit temporal-causal links (e.g., first this happened; then that happened) which guide the speaker's decision on how to order information.

To illustrate further principles that guide the speakers' information sequencing in discourse, Levelt (1982) asked participants to describe a grid of coloured dots without any specific temporal/causal links that might suggest an order (see Figure 2).

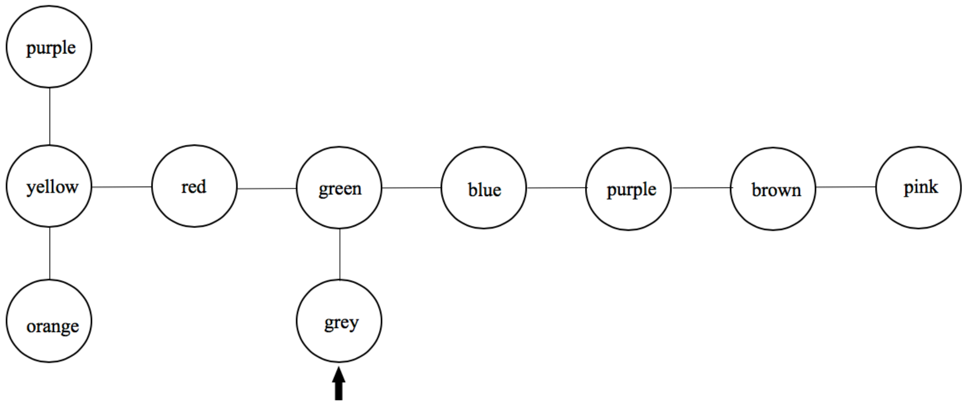

Figure 2: Spatial network participants had to describe in the experiment by Levelt (1982) - reprinted from (Levelt, 1989, p. 104). Arrow represents the point at which participants were instructed to start their description.

The nature of the participants' descriptions led Levelt to establish the principle of connectivity. This states that, when possible, a speaker will choose the most directly linked information unit as the next item in their description (see Figure 2; from grey going straight up to green). However, when a speaker reached a point with multiple options of similar connectivity, Levelt observed that speakers tended to settle on an order that constitutes the least memory load for themselves and the listener (minimal-load principle, Levelt, 1989). In other words, most speakers tried to set up their description as simply as possible. In Figure 2, for example, where the speaker could decide to go from 'green' to either 'blue' or 'red'; the majority of speakers decided to turn right first. Levelt argues that this decision was made because the structure on the right would be much simpler to describe first than the structure on the left. The principles proposed by Levelt offer valuable initial predictions for the most likely information sequence in an individual's discourse.

This thesis primarily focuses on the macrostructural organisation of discourse. Therefore, I will only present a brief overview of the steps that follow the macroplanning stage to facilitate the readers understanding of further theoretical concepts that underlie the research presented in this thesis.

Microplanning

After the speaker has determined the general structure of the message in the macroplanning stage, further shaping is necessary to ensure that the message will be expressed correctly. This mostly concerns discourse organisation at the sentence, phrase or even word level (Armstrong, 2000). Levelt (1989) termed this more finely grained planning step *microplanning*.

Firstly, the speaker needs to decide from which perspective he/she wants to convey the message. Is "the dog chasing the postman" or is "the postman running away from the dog"? Both are perfect descriptions of the same scene and only differ in the perspective the speaker has chosen. Once the speaker has decided on a perspective, he/she can specify the relations between the individual entities that should be mentioned. Additionally, the message needs to have a specific mood, which can either be declarative (e.g., explaining or asserting), imperative (e.g., ordering) or interrogative (e.g., asking). Importantly, while macroplanning focuses on more general features of a message organisation, the processing steps described as microplanning largely depend on the linguistic system in which the message should be produced (Levelt, 1999; Slobin, 1996).

The relationship between thought and language

In the 1950s, the publication of Sapir and Whorf's work on linguistic relativity (as cited in Nuyts & Pederson, 1997) set the stage for a debate that is still ongoing regarding the relationship between language and thought. Sapir and Whorf proposed the hypothesis that the language we speak shapes our thoughts (Nuyts & Pederson, 1997). While this idea was strongly contested at the time, since then, the majority of linguists have agreed that the specific linguistic requirements of a language influence the way we organise our thinking at least to some degree (e.g., Kay & Kempton, 1984; Nuyts & Pederson, 1997).

Intrigued by the idea that language shapes the way people think about events while talking about them, Slobin (1996) investigated Sapir and Whorf's hypothesis across multiple experiments with child and adult speakers of different languages (e.g., Spanish, Hebrew, English, German) and found some evidence that a specific type of thinking is required for speech production - 'Thinking for Speaking'. The participants were asked to describe the same picture story ("Frog, where are you?", see Slobin 1996). All of the languages investigated differed in some aspects of how events are marked grammatically (e.g., whether they have progressive tense forms). Consequently, the linguistic opportunities to communicate the same event, differed across participants. Slobin then analysed similarities and differences in the mental images the speakers conveyed.

Based on this research he concluded that the linguistic requirements and constraints of a language direct the speaker's focus of attention to elements of an event he/she is able to express (e.g., Black & Chiat, 2000; Boroditsky, 2011; Dipper, Black, & Bryan, 2005; Slobin, 1996). For example, when an English speaker wants to say that "the picture is A) *on* the table or B) *on* the wall" there is no need to distinguish if the surface is horizontally or vertically oriented. In contrast, if a German speaker wants to describe the same two scenes, the orientation of the surface needs to be considered to select the correct preposition ("Das Bild ist A) *auf* dem Tisch, or B) *an* der Wand"; see also, Black and Chiat, 2000). Nevertheless, at a non-linguistic level, speakers of both languages are equally able to conceptualise the horizontal or vertical direction of the depicted surfaces (Black & Chiat, 2000).

Even speakers of the same language have different ways that they can express the same event. Here, the speaker's decision is often influenced by the point of view he/she intends to convey (e.g., Labov, 1972). For example, a speaker could say that "the waiter *poured* the wine into the glass", thereby drawing the listener's attention to the wine; while he/she could also say "the waiter *filled* the glass with wine", which draws the attention to the glass (see also, Dipper et al., 2005, p.423). Referring back to the working model of conceptualisation postulated by Levelt (1989), these decisions need to be made at the microstructural level.

Indeed, processes described under the 'Thinking for Speaking' theory mostly concern the microstructural shaping of a message (e.g., choice of words to convey certain perspective). Nevertheless, the speaker's decision to foreground a specific entity can also have implications for conceptualisation at the macrostructural level. In the aforementioned example, the speaker would also be likely to use the sentence "the waiter *poured* the wine into the glass" if he/she next planned to inform the listener about the quality of the wine. As a result, the listener would not need to shift his/her attention and could easily follow the speaker's next utterances. This illustrates that levels of macrostructural and microstructural planning become less distinct and less independent the more complex the discourse becomes (Levelt, 1999).

Similarly, a speaker not only communicates his/her perspective through decisions made at the microstructural level (e.g., choice of verb). Macrostructural decisions like the repetition of phrases or sentences (Labov. 1972) can also be used to emphasise a particular event and communicate a specific point of view (e.g., disbelief of the speaker: "the waiter poured the wine into the glass… he poured the wine into the glass").

Slobin's (1996) 'Thinking for Speaking' research clearly illustrates the strong interaction between thought and language. This sparks the question that underpins the work presented in this dissertation: How does impairment of this interaction and/or impairment of language affect message generation in people with stroke-induced or primary progressive aphasia?

'Thinking for speaking' in aphasia

In the early 1990s, Marshall, Pring, and Chiat (1993) and Byng, Nickels, and Black (1994) reported individuals with aphasia (Marshall et al.: MM; Byng et al.: LC) who showed deficits in expressing events (e.g., too detailed, unusual order of entities mentioned in a simple picture description; Cairns, Marshall, Cairns, & Dipper, 2007) accompanied by non-verbal event-processing difficulties (e.g., distinguishing events from non-events; Byng et al., 1994). Consequently, the authors suggested that the impairments of these two people with aphasia could not be caused by linguistic deficits alone, but that higher level cognitive/conceptualisation processes might also be affected (Byng et al., 1994; Marshall et al., 1993). More information about these studies are presented in the introduction sections of Chapters 2 and 3 and will not be explained in further detail at this point to avoid repetition.

Black and Chiat (2000) linked these findings, for the first time, to Slobin's (1996) "Thinking for Speaking" theory. They argued that in aphasia there is limited access to linguistic information and consequently linguistic constraints are reduced during the preparation of a message during conceptualisation (Black & Chiat, 2000; Levelt, 1989). This leaves the speaker with an underspecified message that is more susceptible to errors in the following processing steps ("spiral of impairment"; Black & Chiat, 2000,p. 75). As a result, individuals with aphasia will show microstructural errors, including the incorrect use of prepositions or verb processing deficits (e.g., Black & Chiat, 2000; Cairns et al., 2007; Dipper et al., 2005). Black and Chiat's theory is further supported by the success of so called 'mapping therapies' that aim to guide the attention of a participant with aphasia and facilitate his/her message preparation, by constraining the linguistic structure of an utterance and making structural features explicit (Black & Chiat, 2000; Byng et al., 1994; Marshall et al., 1993).

Importantly, to date, 'Thinking for Speaking' deficits have only been identified in tasks at the sentence level. For example, a person with stroke-induced aphasia described by Cairns et al., (2007) showed difficulties identifying events in pictures which, in his case, led to verb retrieval deficits and highly detailed picture descriptions (referred to as hypernaming). Interestingly, the participant's discourse did not show this same tendency to convey overly detailed information (Cairns, 2006).

Interestingly, the 'Thinking for Speaking' symptoms identified at a sentence level (e.g., missing central information, too much information; unusual sequencing of information; Cairns et al., 2007) could also be associated with processes Levelt (1989) described at the macrostructural level: information selection and ordering.

Possible impairments of the macrostructural conceptualisation process

In the course of this thesis, I will outline the literature that provides evidence for symptoms described at the microstructural level and/or discourse of speakers with acquired language impairments that may be associated with conceptualisation difficulties at the macrostructural level. The introductions of Chapters 2, 3 and 4, in particular, will present this literature in greater detail. At this point, it is important for the reader to know that the research presented here will investigate three possible markers of conceptualisation deficits at the macrostructural level. In this thesis I will further refer to them as 'symptoms' of possible conceptualisation deficits or simply 'macrostructural symptoms':

1. *Reduced informativeness represented by little essential information* (e.g., Andreetta, Cantagallo, & Marini, 2012; Cairns et al., 2007; Christiansen, 1995; Huber, 1990; Marshall et al., 1993; Nicholas & Brookshire, 1995; Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, & North, 1983).
2. *An unusually large amount of non-essential or detailed information* (e.g., Cairns et al., 2007; Dean & Black, 2005; Marshall, 2009; Marshall et al., 1993)
3. *An unusual order of information* (e.g., Cairns et al., 2007; Carragher, Sage, & Conroy, 2015; Manning & Franklin, 2016)

In this thesis, I relate the first two symptoms to the process of 'information selection' and the third symptom to the process of 'information sequencing' as described in the working model of conceptualisation by Levelt (1989, 1999). These three deficits have been reported in a small number of individuals with aphasia, but have only partly been associated with macrostructural discourse organisation (e.g., Christiansen, 1995; Huber, 1990; Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, & North, 1983). As described before, some of these have only been identified at the sentence level (Cairns et al., 2007; Marshall et al., 1993). Consequently, in this thesis, I investigate 1) if the symptoms outlined by the thinking for speaking literature in aphasia, also occur at the macrostructural level of discourse and if they do, 2) do they occur for the same reason (e.g., event processing difficulties) or, in other words, which underlying mechanisms cause these macrostructural symptoms.

Therefore, my thesis extends on the traditional 'Thinking for Speaking' literature and investigates the relation between language impairments and conceptualisation processes at the macrostructural level in people with neurological language disorders.

Analysing the macrostructural organisation of discourse

Analysing the discourse of people with aphasia is one of the most commonly used methods to gain a comprehensive overview of an individual's expressive abilities. Several studies have also included an analysis of macrostructural features like topic maintenance, global and local coherence, and the overall informativeness (e.g., Armstrong, 2000; Armstrong, Ferguson, & Simmons-Mackie, 2013; Armstrong & Ulatowska, 2007; Linnik, Bastiaanse, & Höhle, 2016; Marini, 2012; Marini, Andreetta, Tin, & Carlomagno, 2011; Ulatowska et al., 1983).

Armstrong (2000) distinguished three different approaches to analyse discourse. Structural approaches focus on microstructural discourse elements (sentence, phrase or even word level). In contrast, functional approaches analyse more general aspects like the communicative success, turn taking or topic maintenance (Armstrong, 2001). The third type of analysis approach - the cognitivist approach - is most relevant for the investigation of the research questions of this thesis. Cognitivists are mostly interested in the overall organisation of discourse. However, apart from Levelt's (1989) working model, outlined above, that describes the organisation of discourse in terms of macro- and microplanning, the organisation of discourse can be described and consequently analysed in numerous ways.

Organisation of discourse

While Levelt (1989) outlines the conceptualisation processing steps necessary to mentally prepare speech production, other authors describe discourse with a more functional point of view (e.g., What is the purpose of this discourse). Longacre (1983) proposed that each monologue discourse can be characterised in terms of its '*contingent temporal succession*' (temporal order of events) and '*agent orientation*' (the importance of who is performing the action). Based on these two features, Longacre outlines four fundamentally different discourse genres: narrative, procedural, behavioural and expository discourse. *Expository discourse*, for example, is understood as a type of discourse in which neither the temporal order nor the involved characters are of any specific importance. In contrast, Longacre (1983) defines *narrative discourse* as a genre in which the discourse follows a strict temporal order of individual events that build on each other. Moreover, narrative discourse shows a strong agent orientation. In other words, in this genre, it is important to convey which characters are involved in the events and who is performing the action. Labov (1972) defines the structure of narrative discourse in greater detail and outlines six essential elements of narratives: Abstract; Orientation; Complicating action; Evaluation; Result or Resolution and Coda.

While some discourse analyses investigate the structural elements outlined by Labov (e.g., Armstrong, 2000), this thesis focuses on analysing the elements of discourse macrostructure presented in Levelt's (1989) working model. It investigates which, and how many, information units the participants select and how they sequence them. The method - "main concept analysis" - that is, in my opinion, best suited to address this research question will be described in further detail later in this chapter.

Although discourse analysis studies have reported several different approaches to eliciting monologue discourse from people with aphasia (e.g., personal narrative, story retelling), picture descriptions remain one of the most popular discourse elicitation methods in research and everyday clinical practice (e.g., Armstrong, 2000; Linnik et al., 2016).

Eliciting discourse using picture description

Using traditional task instructions like “please tell me what’s happening in the picture” or “tell me everything you see going on” is most likely to elicit descriptive/expository discourse (Longacre, 1983; Olness, 2006). Following such instructions, speakers most commonly produce a list-like account of the individual depicted events and entities without expressing any form of relation between them (Olness, 2006; Olness, Ulatowska, Wertz, Thompson, & Auther, 2002).

While it is more common to use a picture sequence to elicit narrative discourse than descriptions of a single picture, Olness (2006) outlines that pictures of a complex scene that involves some sort of complication or climax would be suitable. Olness mentions the ‘Cookie Theft’ picture from the Boston Diagnostic Aphasia Examination (Goodglass, Barresi, & Kaplan, 1983) as an example for a complex picture which depicts such complications (e.g., “a falling boy and an overflowing sink”; Olness, 2006, p.179). Importantly, the correct picture stimulus alone is not sufficient to elicit narrative discourse in a picture description task, the task instructions also need to emphasise that a temporal order and relationship between the depicted entities needs to be conveyed (e.g., “make up your own story about what happened, with a beginning, a middle and an end”; Olness, 2006, p.179).

While Olness (2006) demonstrated that the latter instruction was very successful in eliciting narrative discourse that conveys temporal and causal relationships between depicted entities in participants with mild language impairment, individuals with more severe language impairments struggled to produce narrative discourse. Some participants even showed more reduced speech output than when they were asked to describe everything they saw happening. Olness (2006) suggested that this might reflect their failed attempt to produce a well-structured narrative.

Another important aspect of picture descriptions is that the speaker does not need to convey any new information to the listener and therefore constitutes a rather unusual communication situation. It has been shown that the listener’s familiarity with a topic might affect the speaker's information selection, as well as the overall coherence of the discourse he/she produces (e.g., Armstrong et al., 2013). In a picture description, in which both interlocutors can see the picture, the speaker might therefore choose to make certain aspects of the message less explicit (e.g., omit seemingly obvious information).

Nevertheless, the predictability of the content a speaker is to convey also constitutes the main strength of picture descriptions as a diagnostic tool. Since the investigator knows which content to expect, it is possible to assess errors like semantic paraphasias (e.g., saying 'woman' instead of 'man'), which would be much harder to detect in a personal narrative whose content is completely unknown to the investigator (Armstrong et al., 2013). Moreover, the predictability of discourse content makes it possible to compare picture descriptions across participants and therefore determine when a pattern arises that is unusual.

The literature reports a large number of different analysis approaches focussing on either structural or more functional aspects of discourse (Armstrong, 2000; Armstrong et al., 2013; Linnik et al., 2016; Marini et al., 2011; Prins & Bastiaanse, 2004). One approach particularly suited to investigation of the macrostructural organisation of discourse by analysing the information selection and content quality of picture descriptions is called *main concept analysis* (e.g., Nicholas & Brookshire, 1995).

Main concept analysis

Yorkston and Beukelman (1980) first introduced the idea of analysing content units in the picture descriptions to better track the treatment progress of participants with aphasia who showed mild language impairments. Content unit were short meaningful phrases (e.g., "on the stool") and/or single meaningful words (e.g., "walking") relevant to the picture stimulus.

Nicholas and Brookshire (1992, 1995) extended this approach and analysed the number and quality of statements - called *main concepts* - in participants' picture descriptions. Main concepts should convey essential elements of the picture but could not contain more than one finite verb (e.g., the boy is on the stool; Nicholas & Brookshire, 1995). While previous discourse analysis approaches also reported the analysis of essential information units (e.g., Ulatowska et al., 1983), Nicholas and Brookshire (1993) were the first to specify exact criteria for how these essential information units - main concepts - could be identified.

Since Nicholas and Brookshire's (1995) first reports, several studies have adapted and modified this main concept analysis approach to investigate the informativeness and general structure of discourse (e.g., Capilouto, Wright, & Wagovich, 2005; Richardson & Dalton, 2016; Tanaka, Branch, Dalton, & Richardson, 2016). A more detailed introduction to the traditional main concept analysis approach as well as its recent modifications is provided in the introduction sections of Chapters 2, 3 and 4 of this thesis.

Summary and thesis overview

Conceptualising and organising our speech production are crucial to ensure successful communication in our daily life. Despite the fact that a close link between conceptualising processes and linguistic abilities is widely acknowledged in the literature, there is still a limited understanding of how far language impairments, for example in aphasia, might be underpinned by broader cognitive deficits at the level of conceptualisation. One of the main factors contributing to this lack of insight, is the methodological challenge involved in measuring conceptualisation as well as in distinguishing between processes that guide speech production (speech planning/conceptualisation) and processes involved at subsequent (linguistic) levels of speech production.

Consequently, this thesis aims to develop a practical and clinically applicable method for identifying deficits in the macrostructural organisation of the discourse of people with stroke-induced and neurodegenerative language impairments that could be underpinned by conceptualisation difficulties. To address this aim, I used a modified main concept analysis method that allows investigation of possible macrostructural symptoms related to participants' information selection and sequencing, using a common clinical diagnostic task (i.e., picture description). I evaluated this method in speakers with stroke-induced aphasia (**Chapter 2**) and with a neurodegenerative form of aphasia (primary progressive aphasia; **Chapter 3**). By investigating populations whose language impairments are caused by different types of brain damages, I aimed to inform general theories of how conceptualisation is organised within the speech production process more holistically.

Given both these populations also have word retrieval impairments, I also aimed to determine the extent to which specific linguistic impairments (i.e. word retrieval) and broader cognitive conceptualisation processes contribute to observed macrostructural symptoms. To achieve this, I use a novel method (modified 'taboo-paradigm' based on Meffert et al., 2011) to experimentally induce a reduction in word availability in unimpaired speakers. This method gains insights into the macrostructural symptoms that occur as a consequence of reduced word availability and enables comparison between the performance of unimpaired speakers with induced limited word availability and speakers with aphasia with word availability impairments (**Chapter 4**).

The final experimental chapter (**Chapter 5**), complements the main concept analysis approach, with eye movement measures to investigate to what extent eye tracking can provide online information on conceptualisation processes during speech production and add further insights into the diagnosis of possible conceptualisation impairments in people with acquired language impairments

Finally, I present a discussion of the overall contribution of this thesis to the literature and outline the clinical implications as well as future research directions (**Chapter 6**).

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CHAPTER 2

The Cat in the Tree – Using picture descriptions to inform our understanding of conceptualisation in aphasia[1]

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Abstract

Conceptualisation is the first step of speech production and describes the process by which we map our thoughts onto spoken language. Recent studies suggest that some people with language impairments have conceptualisation deficits manifested by information selection and sequencing difficulties. In this study, we examined conceptualisation in the complex picture descriptions of individuals with and without aphasia. We analysed the number and the order of main concepts (ideas produced by ≥60% of unimpaired speakers) and non-main concepts (e.g. irrelevant details). Half of the individuals with aphasia showed a reduced number of main concepts that could not be fully accounted for by their language production deficits. Moreover, individuals with aphasia produced both a larger amount of marginally relevant information, as well as having greater variability in the order of main concepts. Both findings provide support for the idea that conceptualisation deficits are a relatively common impairment in people with aphasia.

Introduction

“’Where shall I begin, please your Majesty?’ he asked. ‘Begin at the beginning,’

the King said, very gravely, ‘and go on till you come to the end: then stop.’”

***Lewis Carroll**, Alice’s Adventures in Wonderland (p. 182)*

Every one of us tells stories in our daily conversations. We talk about our experiences and important events in our lives without any effort and with only rare misunderstandings by the listener. But how do we decide where to begin such a story, which information to choose and how to order it? Before we are actually able to start speaking we need to think about, and plan, what we are going to say. Moreover, we need to make this plan quickly to keep the conversation smooth. Levelt (1989) describes this pre-linguistic stage of speaking as *“conceptualisation”*. Nevertheless, what seems so easy to us as unimpaired speakers may pose considerable problems to individuals with acquired language impairments. Surprisingly, however, little is known about the interaction between an individual’s conceptualisation and his/her language abilities. In this paper, we aim to investigate this interaction in more detail by examining what data from picture description can tell us about an individual’s conceptualisation and/or possible conceptualisation deficits.

What is conceptualisation?

Conceptualisation can be understood as the process of forming general ideas on the basis of specific observations and experiences (Chafe, 1990). However, the linguistic literature lacks a concrete definition of the term. Consequently, there are a variety of different understandings of “conceptualisation”. Cognitive linguists have described conceptualisation as an umbrella term that encompasses abstract entities like thoughts and more concrete sensory experiences like the smell or appearance of objects (Langacker, 1986). Conceptualisation has also been described as the mind’s ability to “build models of the world” (Chafe, 1990, p. 90) which is influenced by our expectations, previous knowledge and the context of a specific situation (Chafe, 1990; Langacker, 1986).

In this paper, we focus on conceptualisation as a part of the speech production process. Levelt (1989) describes conceptualisation as the first step of speech production, which entails two main processes: the *macroplanning* and the *microplanning.* During macroplanning we form a speaking intention, select the necessary information and order this information in a way that makes it easy for the listener to follow. Microplanning is a more finely grained process in which we shape the message into a linguistic structure that can be further processed (e.g., assigning thematic roles). In other words, during conceptualisation we transform our thoughts into a structure that can be verbally expressed.

During the conceptualisation process, the linguistic constraints of the language we speak direct our attention to features of the message (e.g., type of motion, orientation of a surface) that we are able to express and/or features that are required to perfectly prepare our message for further processing ("Thinking for Speaking"; e.g., Dipper, Black, & Bryan, 2005; Slobin, 1996). Even though this strong interaction between thinking and speaking is well described in the literature (e.g., Black & Chiat, 2000; Cairns, Marshall, Cairns, & Dipper, 2007; Dipper et al., 2005; Marshall, Pring, & Chiat, 1993; Slobin, 1996), surprisingly little is known about conceptualisation processes in individuals with acquired language impairments (e.g. stroke-induced aphasia).

Conceptualisation deficits in aphasia

Dipper et al. (2005) argue that language impairment might reduce the linguistic constraints that are necessary to optimally prepare a message for speech production, resulting in the production of a linguistically incorrect phrase ("spiral of impairment"; Black & Chiat, 2000). Dipper et al. (2005) propose that, under these circumstances, an individual with aphasia would experience problems at the microstructural conceptualisation level (e.g., choosing a perspective, determining an argument structure). In the individual's spontaneous speech, the symptoms of the effects of linguistic impairments on microstructural planning would be hard to distinguish from purely linguistic deficits (e.g., word retrieval, agrammatism), and indeed from 'pure' microstructural impairments. In this paper, we focus on the macrostructural level, and aim to tease apart linguistic impairments and (non-linguistic) conceptualisation impairments.

A small number of single case studies have described individuals with aphasia who have been argued to show symptoms that could be associated with conceptualisation deficits at the macrostructural level (e.g., Cairns et al., 2007; Marshall, 2009). Cairns et al. (2007) described the case of Ron. His spontaneous speech was agrammatic, characterised by noun and verb retrieval difficulties with a high proportion of noun-phrases and few verb-argument structures. Cairns and colleagues evaluated Ron's ability to process depicted events using a picture description task (Order of Naming Test; Cairns, 2006). The stimuli consisted of simple action pictures with three entities (agent, patient and instrument; e.g. a depiction of a fairy spraying a swimmer using a hose). Ron mentioned many details of the picture, for example: *"tap, hose, and pixies, elf, woman long hair – no short – no bob and pixie and then swimming woman, and cap, obviously, and [gestures goggles]"* (Marshall, 2009, p. 6). In contrast, most unimpaired participants restricted their picture descriptions to the three depicted entities (e.g., "The fairy sprays the swimmer with a hose."). The authors interpreted Ron's overly detailed descriptions as an inability to select the most important information (Cairns et al., 2007). Indeed, even when Ron was asked to simply name the depicted entities, he listed about eight different objects, while unimpaired participants never mentioned more than three. In addition to Ron, we found only two further individuals with aphasia who have been reported to produce a large proportion of information unrelated or marginally relevant to the event (e.g., clothing of depicted entities) in a picture description task (Dean & Black, 2005; Marshall, Pring, & Chiat, 1993). Both were described as having a primarily agrammatic symptom pattern, like Ron.

Moreover, Ron produced the entities he mentioned in a seemingly random order, while unimpaired participants tended to mention the individual entities in the order in which they appeared in a sentence. Similarly, Manning and Franklin (2016) observed temporal sequencing errors in the Cinderella narratives of some of the 22 people with aphasia and 10 unimpaired speakers. In this experiment, the participants were reminded of the Cinderella story using picture cards supplement by a brief description by the experimenter and then told to freely retell the story. Manning and Franklin analysed the macrostructural (e.g., story elements, discourse marker, temporal sequencing) and microstructural features (e.g., omission of verbs, incorrect use of pronouns) of the narratives. They found that individuals with aphasia produced significantly more sequencing errors than unimpaired speakers (e.g., “the prince and the princess were dancing […] *Cinders was going to the ball”, Manning & Franklin, 2016, p.423). Interestingly, Manning and Franklin did not find any significant correlations between microstructural deficits (e.g., omission of verbs or wrong pronoun use) and temporal sequencing errors. Consequently, the authors suggested that temporal sequencing does not seem to be influenced by linguistic deficits at the microstructural level.

Sequencing errors were also observed in the study by Carragher, Sage and Conroy (2015). Two of their four participants with aphasia produced simple video recounts out of sequence (e.g., Scene 1 - 3 - 2 - 4). When the narrative became more complex (more than 2 actors, 6 scenes) all of the language impaired participants produced at least one sequencing error. In contrast no such errors were observed in the narratives of unimpaired control participants.

Another case (LC) with presumed conceptualisation difficulties is reported by Byng, Nickels & Black (1994). While LC did not produce overly detailed picture descriptions or sequencing errors, she presented with considerable verb processing difficulties and showed deficits when discriminating pictures of events (e.g., someone driving a car; a newspaper being blown along the street) and non-events (e.g., an empty street). Similarly, the participant, MM, described by Marshall et al. (1993) had difficulties identifying the same action when it was depicted in different contexts (e.g. pushing a pram vs. pushing a wheelbarrow). Finally, Dean and Black (2005) found that the verb production of the case reported (EM) in their study was affected by conceptual verb features (e.g., situation type) rather than by features like frequency and/or familiarity. Dean and Black argued that these symptoms might be underpinned by an impairment in the connection between general event processing (e.g., identifying relationships between entities) and the language structures used to describe events (e.g., verbs, argument structure). Thus, verbal and non-verbal event processing difficulties may be valuable predictors of (macrostructural) conceptualisation impairments in people with aphasia (Cairns et al., 2007; Byng et al., 1994, Marshall et al., 1993).

To summarise, based on the literature, there are three possible symptoms that may be associated with underlying conceptualisation problems: 1) reduced informativeness (Carragher et al., 2015; Cairns et al., 2007; Marshall et al. 1993), 2) large numbers of irrelevant details (Cairns et al., 2007; Dean & Black, 2005; Marshall et al., 1993) and 3) content sequencing errors (Manning & Franklin, 2016, Carragher et al., 2015; Cairns et al., 2007).

Considering the strong link between conceptualising and speaking we were surprised by how few cases have been reported with symptoms that point to a conceptualisation deficit. Hence, we were interested if these symptoms could be observed in a larger population of individuals with aphasia using a clinically feasible picture description task.

Investigating conceptualisation in narrative discourse

Narratives are not merely descriptive listings of events and facts, they also reflect our representations of the world (Chafe, 1990). Thus, narrative discourse can tell us a lot about how individuals perceive the events they talk about. A wide variety of structural (e.g., Marini, 2012; Prins & Bastiaanse, 2004) and functional (e.g., Armstrong, 2000; Armstrong, Ferguson, & Simmons-Mackie, 2013) analysis approaches have been used to evaluate specific linguistic features (e.g., use of verbs or pronouns) and discourse pragmatic (e.g. turn-taking behaviour) in aphasia and unimpaired individuals. However, general conceptual processes underpin our ability to make discourse (Langacker, 2008; Levelt, 1989) and hence, people with aphasia who experience conceptual impairments would be predicted to make discourse errors. Specifically, we would expect them to show impairments in macrostructural features such as information selection and information ordering and/or microstructural features like perspective taking (e.g., Cairns et al., 2007; Marshall, 2009).

Few discourse analysis approaches have focused on the selection of discourse information and the quality of the content. Yorkston and Beukelman (1980) presented pioneering work in this field. They analysed content units in the picture descriptions of unimpaired and language-impaired speakers (Cookie Theft; Goodglass, Barresi, & Kaplan, 1983). Content units were defined as "a grouping of information that was always expressed as a unit" (Yorkston & Beukelman, 1980, p. 30). Although this analysis provided some information about the informativeness of the participants' picture description, it did not evaluate whether these content units were used in a context that described the depicted scene.

Nicholas and Brookshire (1993, 1995) and Richardson and Dalton (2016) analysed the informativeness of a picture description by focusing on the concepts produced. When looking at the picture descriptions of unimpaired speakers, they defined concepts as statements that contained one main verb only and represent the essential information of the depicted event (Nicholas & Brookshire, 1995). Nicholas and Brookshire (1995) asked 10 experienced speech pathologists to provide a written description of the Cookie Theft picture descriptions and collected oral descriptions of the same picture from 20 unimpaired participants. They considered that every **concept** that was mentioned by seven of the 10 speech pathologists was essential to the picture description and therefore identified as a **main concept**. When these concepts were also mentioned by at least 14 unimpaired individuals in their oral descriptions, they were confirmed as main concepts and added to a final list. Some main concepts identified in these studies were very clearly defined pieces of information (e.g., "The woman is doing the dishes"). However, due to the large variability in oral picture descriptions other main concepts were very broad and included a variety of statements (e.g., "some mention of a plausible action by the girl or location of the girl."). Hence, main concepts rather represent a broad idea or entity that should be mentioned in the picture description than a particular propositional phrase in a participant's description.

In contrast to Nicholas and Brookshire's 70% criterion, Richardson and Dalton (2016) argued that a concept could be considered essential when it was mentioned by at least 33% of participants (in analysis of the picture descriptions [Cinderella story and Broken Window picture sequence] of 92 unimpaired participants). However, they also examined stricter criteria of 50% or 60%, and found that these did not lead to significant changes in the number of relevant main concepts observed.

Some authors have even identified main concepts in the absence of a representative control group (e.g., Capilouto, Wright, & Wagovich, 2005; Ramsberger & Rende, 2002). In these cases, independent raters were asked to identify concepts, as defined above, for a particular target picture or topic of discourse. Any concept that was identified by at least two out of three raters (or a similar proportion in case of more raters) were then defined as main concepts (e.g., Capilouto et al., 2005; Ramsberger & Rende, 2002).

Identifying main concepts in the discourse of individuals with language impairments is more challenging. Due to the lack of content words and/ or grammatical markers the ideas the participants convey are not always clearly interpretable. Hence, adaptations to the previously established definitions of concepts and main concepts are required.

The approach proposed by Nicholas and Brookshire (1995) is that most commonly used to identify main concepts in discourse of speakers with aphasia (e.g., Capilouto et al., 2005; Carragher et al., 2015). Nicholas and Brookshire devised a set of rules to determine which statements can be counted as main concepts. They proposed that, as long as a statement is comprehensible to a listener who is familiar with the target picture and context, it should be counted as a main concept. Hence any grammatical, phonological or semantic errors can be ignored as long as the general idea is conveyed (e.g., "the man dishes drying" instead of "the woman is drying the dishes"). Nicholas and Brookshire suggested that two independent raters should identify main concepts and compare and discuss their results, solving any disagreements by consensus.

Using this approach, Nicholas and Brookshire (1995) found that half of the individuals with aphasia produced fewer main concepts than unimpaired participants. Hence, many of the individuals with aphasia either did not have any deficits in selecting the most important information or this measure was not sensitive enough to discriminate between unimpaired individuals and individuals with aphasia (Nicholas & Brookshire, 1995).

In addition to the identification of main concepts in the participants' discourse, Capilouto et al. (2005) were interested in how concepts were semantically linked. Following Nicholas and Brookshire's (1995) definition of a concept, a sentence like "The man tried to get the cat, but his ladder fell and now he is stuck." would have been split into three different concepts: 1) The man tried to get the cat 2) The ladder fell 3) The man is stuck. As a result, the semantic relationship the participant originally expressed between concept 2) and 3) would be lost for further analyses. Consequently, Capilouto and colleagues accepted statements that contained more than one verb as main concepts, so that the relationships expressed between individual entities could be assessed.

However, not all individuals with aphasia are able to convey links between ideas verbally or link them correctly. Hence, poorly linked ideas could simply be a consequence of the linguistic impairments rather than impaired conceptualisation. Analysing the order in which the participants present information regarding an event (verbally and non-verbally) might circumvent this issue.

As discussed earlier, the order in which information is produced is assumed to reflect the participants' conceptualisation of relationships between individual information units and is also considered less dependent on the participants' linguistic abilities (e.g., Manning & Franklin, 2016; Carragher et al., 2015) than the number of concepts produced. Therefore, unusual ordering might be a valuable marker for conceptualisation difficulties. Such an analysis could get us one step closer to solving the diagnostic dilemma of distinguishing between spontaneous speech symptoms that are primarily caused by linguistic impairments and symptoms that might be underpinned by conceptualisation difficulties.

Study aim

In this study we aimed to identify evidence for possible conceptualisation deficits in a larger population of individuals with aphasia by examining two macrostructural elements in a picture description task: information selection (e.g., number and quality of main concepts) and information order (e.g., order of main concepts). We predicted that individuals with conceptualisation deficits would produce fewer main concepts, more irrelevant detail and have greater variability in the ordering of main concepts than unimpaired participants. To examine the extent to which these measures were affected by linguistic deficits, we evaluated the influence of 1) the number of words, verbs, and nouns; as well as, 2) the participants' verb and object naming ability. In particular, we expected poor verb production to be associated with macrostructural difficulties.

General Method

Participants

All participant data in our study was obtained from the AphasiaBank database (MacWhinney, Fromm, Forbes, & Holland, 2011). Different research groups contributed data to AphasiaBank from 293 different English-speaking individuals with aphasia and 193 unimpaired individuals. Every participant was assessed following the same test protocol. This protocol included speech and language assessments like the Western Aphasia Battery (WAB; Kertesz, 1982), the 'Verb Naming Test' (VNT; Cho-Reyes & Thompson, 2012), various picture description tasks, medical history and demographic information about each participant. We excluded all participants who were reported to have visual impairments like neglect or hemianopia (Aphasia: 3; Controls: 0) or were left-handed (Aphasia: 40; Controls: 12). We then selected the first 50 unimpaired participants from the database, who served as control participants without any cognitive difficulties, and randomly selected 50 individuals with aphasia (using random number generation). After first inspection of the picture description data we had to exclude three further participants with aphasia who did not produce any analysable verbal response (e.g., they just shook their head). We subsequently selected three new individuals with aphasia to give a total of 50 participants in each group. A comparison of the demographic data of both experimental groups revealed an age difference, with the mean age of unimpaired participants being slightly, but significantly higher than the mean age of individuals with aphasia (Unimpaired individuals: mean age = 72;8 ± 6;1; Individuals with aphasia: mean age = 69;1 ± 11;4; $t(98) = 2.0319$: p=0.04487). No significant differences were found in the gender distribution (Unimpaired individuals: 25 females, Individuals with aphasia: 25 females) or in mean years of education (Controls = 15.2 years; Individuals with aphasia: 15.5 years).

The type of aphasia was determined with the WAB. The sample included 19 individuals with Broca's aphasia, 11 with conduction aphasia, 15 with anomic aphasia, 3 with Wernicke's aphasia, 1 with trans-cortical sensory aphasia and 1 remained unclassified. The severity of impairment, as defined by Western Aphasia Battery Aphasia Quotient, ranged (WAB-AQ; Kertesz, 1982) from mild (maximum WAB-AQ = 96.1) to severe (minimum WAB-AQ = 45.5; overall mean WAB-AQ = 72.2 ± 14.4). Fluency of speech was recorded in the database as determined by the clinical impression of the AphasiaBank contributor (non-fluent: 22 (19 Broca's, 3 anomic); fluent: 28). A comparison of the severity of aphasia measured by WAB-AQ between participants classified as fluent or non-fluent revealed a significantly more severe impairment in non-fluent speakers (non-fluent: 67.6 (12.9); fluent: 76.8 (14.5); $t(48) = -2.35$; $p<.05$). We also extracted Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1883) and VNT (Cho-Reyes & Thompson, 2012) results for all individuals with aphasia from the AphasiaBank database (see Appendix A for complete list of demographics).

Materials

The connected speech samples in this study were elicited using the "Cat Rescue" picture (Nicholas & Brookshire, 1993; see Figure 1).

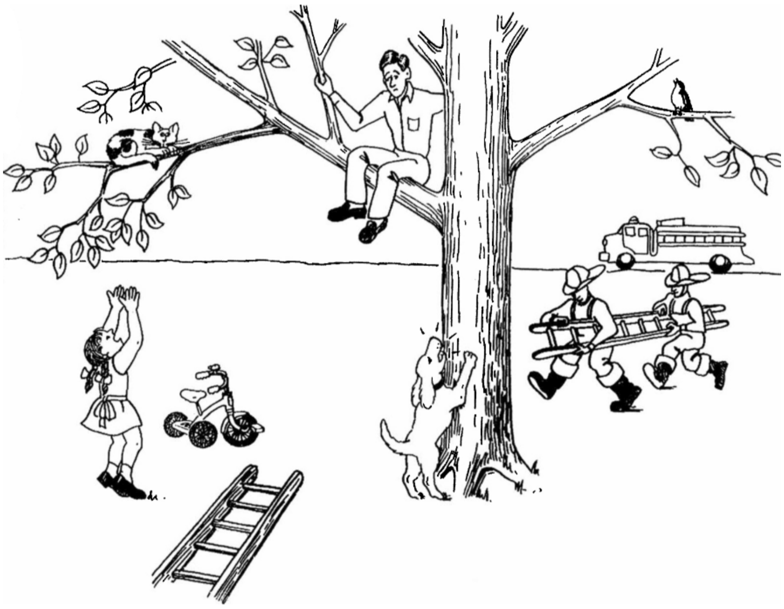

Figure 1: Cat Rescue picture (Nicholas & Brookshire, 1993)

Nicholas and Brookshire developed this task to prompt narrative discourse in form of a story-like picture description. In order to accurately describe the picture, participants had to infer interactions between the depicted elements. The protocol required each participant to "*describe the picture by telling a story with a beginning, a middle and an end.*" (MacWhinney et al., 2011, p. 1288, see also Olness, 2006). Transcripts and videos of each picture description were available on the AphasiaBank database. Consequently, both verbal and non-verbal responses were used for our analysis of main concepts and non-main concepts (see Analysis 2 for further detail).

Experimental investigation

We conducted six different analyses to provide a comprehensive overview on the quality, number and order of main concepts in the participants' picture descriptions:

1) Identification of concepts and main concepts in unimpaired speakers
2) Analysis of main concepts in individuals with aphasia
3) Analysis of non-main concept statements
4) Analysis of the order of main concepts
5) Analysis of factors influencing concept production

Below, we present the procedure of each analysis immediately followed by the corresponding results.

Analysis 1: Identifying concepts and main concepts in unimpaired speakers

In this analysis we first investigated the individual concepts unimpaired subjects produced in their picture description. Guided by Nicholas and Brookshire (1995), we defined a **concept** as a statement that contains only one verb and conveys information about the picture. Subsequently, we identified which of the concepts produced by unimpaired speakers could be classified as essential to the picture description and therefore identified as **main concepts**.

Concepts

Method

To identify the concepts, we first listed every phrase each participant produced in his or her description. We excluded comments about the participants' own performance (e.g., "that was not good") from further analysis.

We then collapsed across phrases that constituted a single idea (hereafter: concept) by asking three independent raters to identify phrases that expressed a similar meaning despite being differently worded. For example, "The cat ran up the tree" and "The cat got up the tree" were combined to form a single concept "*The cat climbed/ is in the tree [*motion or location of the cat]*). The raters were also asked to identify when a listed phrase conveyed two different concepts. For example, the phrase *"The dog chased the cat up the tree."* was treated as two different concepts in our analysis: *(1) The dog chased the cat* and *(2) The cat is up the tree*.

Results

We identified 182 different utterances across all unimpaired participants. All three raters agreed in their judgement for 108 phrases (60%), which were sorted into 47 different concepts. A decision about the remaining 74 phrases was gained by consensus, resulting in 8 further concepts. Hence, all 182 utterances were merged into 57 different concepts (see Appendix B).

Main concepts

Of the 57 concepts identified, some, however, were mentioned by few or even only one unimpaired participant and showed only marginal relevance to the core story depicted (e.g. "The man thinks he is a squirrel."). Thus, the next analysis determined which of the identified concepts were relevant to the depicted story and were, therefore, main concepts.

Method

Our study included a larger control sample than that previously reported by Nicholas & Brookshire (1995). Hence, we decided to adopt a more liberal criterion for the definition of a main concept: We followed Richardson and Dalton (2016) and decided that statements that were produced by 60% or more unimpaired participants can be identified as main concepts (rather than 70% for Nicholas and Brookshire). This (admittedly arbitrary) decision was also based on the assumption that a concept that was produced by more than a half of all unimpaired participants must be relevant and important to the depicted story.

Results

We identified eight concepts that were mentioned by more than 60% of all unimpaired participants. Critically, we found that no individual concept about the depicted entities GIRL and DOG reached the 60%-threshold. However, the entities themselves were mentioned by the majority of unimpaired participants (GIRL: 90% of participants, e.g., *The girl is crying*; *The girl wants the cat; The girl is standing there*; DOG: 62% of participants, e.g., *The dog is barking; The dog is worried; The dog tries to bite the man*). This was not the case for statements about other depicted entities like BIRD (30%) and TRICYCLE (0%). We therefore concluded that while control participants were not sure about the exact role of the entities GIRL and DOG in the depicted event, for the majority of participants these entities were perceived as relevant. Consequently, following the approach of Nicholas & Brookshire (1995), we merged all concepts that were produced about the GIRL or about the DOG and included them as broadly defined main concepts representing "*any mention*" of the entities ("*Any mention about the girl [*negative emotion, action, location]*"; "*Any mention of the dog [*appearance, mood, motivation, action]*") in our final main concept list. The final list therefore comprised 10 main concepts for the Cat Rescue picture (see Table 1).

On average, unimpaired individuals produced 8.14 (SD: ± 1.14) main concepts in their picture description.

Table 1: List of main concepts that were mentioned by more than 60% of unimpaired participants, alternative wordings for each concept and the position in which they were produced within the description

Order[1]	Main Concept	Alternative	Mentioned by (%)[2]
A	The cat climbed/ is in/ is stuck in the tree [*motion up or *location]	e.g., hiding in the tree/ sitting in the tree/ is stuck/ needs to be rescued/ won't come down/ caught/ won't jump down, got up/ ran up [*any kind of movement to get up the tree]	96
B	Any plausible mention of the girl [*negative emotion/ *plausible action/ plausible location]	e.g., is worried/ is upset/ is crying/ is helpless/ is shouting/ is calling the cat/ screaming for the cat/ trying to get the cat/ hopes the cat will fall in her arms/ cannot reach the cat/ tries to catch the cat/ is standing underneath the tree / noticed her cat/ found the cat/ is off the bike/ is on the ground/ was on her bike/ sees her cat in the tree/ finds the man in the tree/ playing with the cat and the dog/ playing in the park/ was riding the bicycle/ lost the cat/ get her dad/ called her dad/ summoned her dad/ yelled for help/ told her mother/ asked the man to help/ called the dog to help	90
C	The man wants to get the cat [*plausible motivation to climb the tree]	e.g., wants to rescue the cat/ cannot reach the cat/ tried to get away from the dog [*any plausible motivation that explains why the man is in the tree]	74
D	The man climbed/ is in/ is stuck in the tree [*motion up or *location]	e.g., went up/ goes up/ got up/ got himself up [*any kind of movement to get up the tree], is in/ is sitting/ is stuck/ is caught	98
E	The ladder is lost [*any indication that the ladder cannot be used]	e.g., the ladder fell down/ got out/ dog knocked the ladder over/ wind blew the ladder over	72
F	Any plausible mention of the dog [*any expression that indicates "making noise"/ *appearance/ *motivation]	e.g., growling/ making a lot of noise/ disturbs everyone/ went bananas/ comes/ is there/ is upset/ is concerned/ wanted to see where the man went/ thinks this is crazy/ trying to help the man down [*any motivation that explains why the dog is there/ barking]	60

G	Someone [*any indication of a person] must have called the fire brigade	e.g., the mother called/ I don't know how they got the fire brigade/ neighbours called/ girl called [*any explanation or mention of how the fire brigade knew that they had to come]	66
H	The fire brigade is coming [*any mention of their arrival at the scene]	e.g., fire brigade is there/ fire brigade is going by/ arriving/ comes running/ driving the truck over/ showing up [*any mention of the fire brigade's arrival at the scene]	94
I	The fire brigade brings a ladder [any indication of them having/ bringing a second ladder]	e.g. brought a ladder/ carrying a ladder OR together with concept: coming with a ladder / showing up with a ladder	68
J	The fire brigade rescues them [*help/rescue or anything similar]	e.g., retrieves the man/ helps the man and the cat/ gets them down/	96

Note: [1]Order = Position relative to other concepts in which the concept was mentioned most often; [2]Mentioned by (%) = Percentage of controls who produced the specific concept

Analysis 2: Main concepts in individuals with aphasia

Method

In this analysis we identified main concepts in the picture descriptions of individuals with aphasia. Following the approach of Nicholas and Brookshire (1995), any statement that could be understood by a listener who is familiar with the target picture and the context, and could be assigned to one of the 10 main concepts, was identified as a main concept. As long as this criterion was fulfilled, grammatical, phonological and/or semantic errors were ignored However, we also made minor adjustments to the analysis procedure proposed by Nicholas and Brookshire (1995). Since we were interested in how the participants conceptualise the picture in terms of the information they deem relevant and choose to convey, rather than in their ability to linguistically express this information, we accepted both verbal and non-verbal responses (e.g., *"this {points: cat} and {slides finger up the tree} and man {slides finger up the tree}"*). In addition, if a participant named one of the depicted entities or pointed at one of them without giving additional information, the response was scored as an instance of the main concept about the respective entity that was mentioned by most of the unimpaired controls (e.g., *"man {pointing at man}"* = and instance of the main concept '*The man climbed/ is in the tree'; see*

Appendix B). There were only 18 main concepts of this kind (of the 263 main concepts identified for participants with aphasia) and this only applied to eight participants with aphasia.

After the first author had identified all main concepts in the participants' picture descriptions, we randomly selected 20 descriptions which were analysed by a second independent rater. The raters agreed in their identification of 95% of main concepts. In case of disagreement a decision was made by consent. All utterances that could not be assigned to a main concept were listed separately.

Results

A two-sample t-test revealed that individuals with aphasia produced significantly fewer main concepts than the group of unimpaired participants (mean: 6.08 (SD: ± 1.98); t (98) = -6.559; p<.001, see Table 3). Crawford and Howell's modified t-test for single cases (singlims, Crawford, Garthwaite, Azzalini, Howell, & Laws, 2006) indicated that participants who produced less than seven main concepts (MC), differed significantly from unimpaired participants (6 Main concepts: t = -1.86; p=.034). This analysis showed that half (25) of the individuals with aphasia produced significantly fewer main concepts than unimpaired subjects (see shaded area in Figure 2).

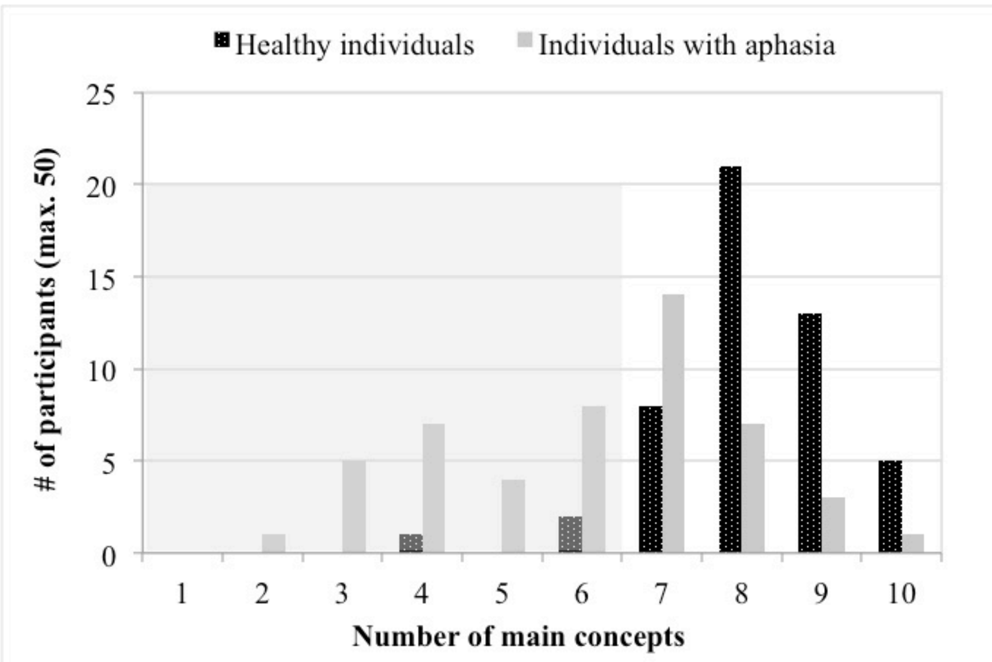

Figure 2: Frequency of total number of main concepts produced per narrative by unimpaired participants and individuals with aphasia. (Shaded area indicates the number of main concepts that are significantly lower than the unimpaired subjects)

Of the individual main concepts, eight were produced by significantly more unimpaired participants than individuals with aphasia (Fisher-exact: all $p<.01$ (one-tailed), see Figure 3). In contrast, significantly more individuals with aphasia produced a main concept about the DOG (Fisher-exact: $p=.0125$, see Figure 3). However, just as many individuals with aphasia as unimpaired participants produced a main concept relating to the GIRL (see Figure 3).

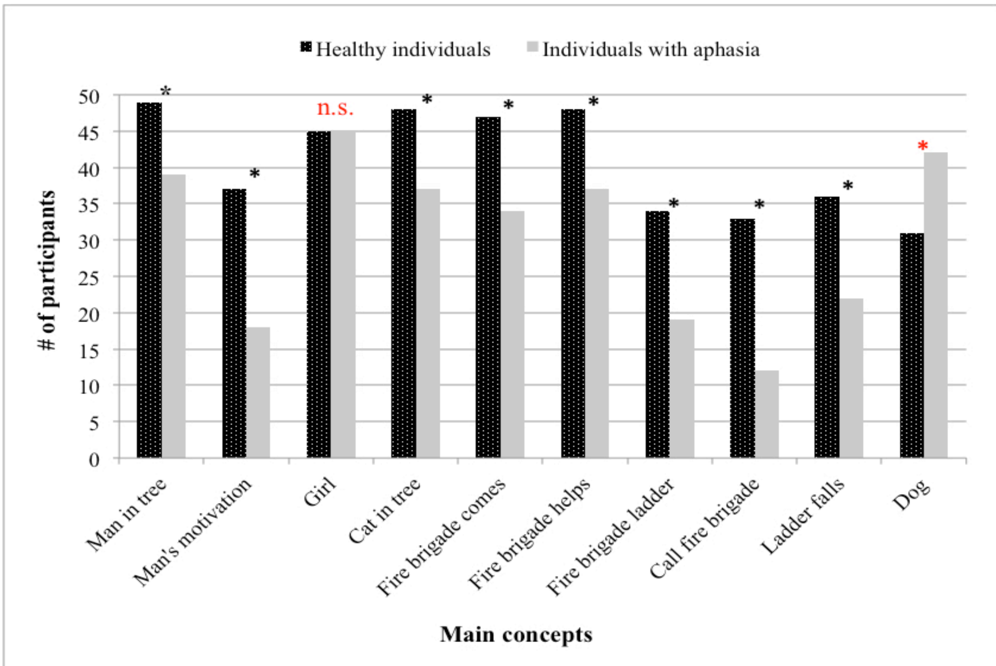

Figure 3: Number of individuals with aphasia and unimpaired individuals that produced each individual main concept (* = p<.05 (Fisher Exact Test), n.s. = p>.05).

Discussion

In line with our predictions, we found that some individuals with aphasia produced significantly fewer main concepts than unimpaired participants. Interestingly, this finding is not consistent across all individual main concepts. Consequently, we suggest that the participants' expressive language impairment might not be the only explanation for the reduced number of main concepts. Conceptualisation impairments would be another possible explanation for the reduced number of main concepts in this first analysis. Cairns et al. (2007) hypothesised that conceptualisation impairments would be characterised by the production of a relatively large amount of irrelevant detail. Consequently, the next analyses evaluate the production of non-main concepts, comparing the production of unimpaired speakers and the individuals with aphasia.

Analysis 3: Non-main concept statements

Method

We first counted the number of statements that did not concern one of 10 main concepts in the group of unimpaired participants. We identified three different types of non-main concept statements in their picture descriptions: 1) plausible ideas that were produced by less than 60% of all unimpaired participants (e.g., "the man is afraid to come down"), 2) general comments (e.g., "this is a real mess"; "that's the end") and 3) marginally relevant information. Marginally relevant information was defined as statements that could not be plausibly inferred from the picture (e.g., "the man thinks he is a squirrel"; "mom looks out of the house") or detail (e.g., "the girl has a ponytail"). These three categories were sufficient to categorise all the utterances for unimpaired speakers, however, for people with aphasia it was necessary to define two new categories: 4) semantically empty/indeterminate statements (e.g., "he is could have in her hurry") and 5) associations (e.g. for FIRE BRIGADE: "I worked for those").

Results

Unimpaired participants produced on average 1.44 (SD: 1.77; range 1-11) non-main concept statements per picture description. Individuals with aphasia produced, on average, significantly more non-main concept statements than unimpaired individuals (mean=2.52 (SD: 2.55; range 1-10); t (98) = 2.681; p<.01). Single cases analysis (singlims, Crawford et al. 2006) indicated that participants with aphasia who produced more than five non-main concepts, differed significantly from unimpaired controls (5 non-main concepts: t=1.991; p<.026). We identified 11 individuals with aphasia who produced significantly more non-main concepts than unimpaired participants, two of whom also produced a significantly lower number of main concepts.

The majority of the unimpaired participants' non-main concept statements were plausible ideas (49%) or general comments (32%; see Table 2). Comments were used to express narrative structure of the picture description (e.g. "this is the end"; "they lived happily ever after") or to give a general remark about the scene (e.g., "we have a real mess here"). Of the 14 non-main concepts classified as marginally relevant information, half were produced by a single participant. The remaining seven marginally relevant non-main concepts were produced by seven different participants.

Table 2: Distribution of non-main concept statements in unimpaired individuals and individuals with aphasia and comparison between non-main concepts statements produced in both groups (Mann-Whitney U - test)

	Controls		**Individuals with Aphasia**		**Controls vs. Individuals with Aphasia**	
	Total (%)	Mean (SD)	Total (%)	Mean (SD)	z	*p*
Plausible ideas	35 (49%)	0.7 (1.07)	46 (36%)	0.9 (1.6)	.95	.17
Comments	23 (32%)	0.46 (0.61)	31 (25%)	0.62 (1.14)	.80	.21
Marginally relevant information	14 (19%)	0.28 (1.03)	26 (21%)	0.52 (0.90)	2.08	.019*
Associations	0 (0%)	0	4 (3%)	0.08 (0.34)	1.45	.073
Semantically empty	0 (0%)	0	19 (15%)	0.38 (0.75)	3.55	<.001***

*** $p<.001$; ** $p<.01$; *$p<.05$

A Chi-square test revealed a significant difference between the overall pattern of non-main concept statements produced by unimpaired participants and individuals with aphasia (χ^2 (4) = 15.72; $p<.01$). As for unimpaired individuals, individuals with aphasia most commonly produced plausible ideas (e.g., "maybe the man jumps off"), comments (both structural (e.g., "the next thing that is happening is"), and general comments (e.g., "that's kind of funny") and marginally relevant information ("e.g., the girl has ponytails."). Overall, participants with aphasia mentioned significantly more marginally relevant statements than unimpaired participants (see Table 2). However, none of the participants with aphasia produced more than four of these statements within one picture description.

Further we observed the production of some associative information (e.g., *I have firemen in my family)* and semantically empty statements, which none of the unimpaired participants produced. Individuals with aphasia produced significantly more semantically empty statements than unimpaired participants (see Table 2).

Discussion

As predicted, our results showed that, on average, individuals with aphasia produced more non-main concepts than unimpaired individuals. Nevertheless, the proportion of participants who showed an increased number of non-main concepts was relatively small (11 out of 50 participants). For these individuals, we suggest that conceptualisation difficulties could underpin the increased number of non-main concepts.

However, the pattern of increased production of non-main concepts was not consistent across all subtypes of non-main concepts. In line with Cairns et al.'s (2007) hypothesis, we found that, overall, participants with aphasia in our sample produced significantly more marginally relevant information than unimpaired participants. Nevertheless, we did not identify any individual with aphasia who produced an overly detailed picture description as reported for some cases with possible conceptualisation difficulties (e.g., Cairns et al., 2007). Interestingly, the non-main concepts produced by participants with aphasia in our study were not simple listings of details, as reported for the case of Ron (Cairns et al., 2007). It is possible that more complex scenes, like the "Cat Rescue", elicit different kinds of non-main concepts than simple event pictures as used by Cairns et al. (2007).

To further support the hypothesis of underlying conceptualisation deficits in some of the people with aphasia, we investigated the order in which the participants produced the individual main concepts in Analysis 4.

Analysis 4: Order of main concepts

Putting information in an order that makes it easy for the listener to follow is an essential part of conceptualisation. Thus, a large discrepancy between the main concept order of an individual with aphasia and the group of unimpaired subjects could point to conceptualisation difficulties. To investigate if the participants with aphasia were able to understand and convey links between given information despite their speech production impairments, we analysed the order in which this information was mentioned.

Method

We first identified the exact main concept order of each unimpaired individual and calculated the median position for each main concept across the group of unimpaired individuals (see Order column in Table 1, earlier).

Next, we calculated a Difference-in-Order-ratio (DiO ratio) to determine the difference between the individual main concept order in each participant's (unimpaired and participants with aphasia) picture description and the median main concept order was established on the basis of the picture description of the unimpaired speakers in this study (see Appendix C for full description of the method). This DiO ratio can have any value between 0 and 1 and for each individual represents the number of differences from the median main concept order. Hence, the higher the DiO ratio the larger the deviation between an individual's order of main concepts and the median main concept order. For example, if a participant produced all ten main concepts and showed two differences from the median concept order (e.g., producing concepts in the order: **2** - 1 - **4** - 3 - 5 - 6 - 7 - 8 - 9 - 10) the DiO-ratio would be 0.04. Changes in the DiO ratio also depended on the number of total main concepts the participants produced. For example, if a participant only produced eight main concepts and two differences from the main concept order the DiO ratio would be 0.07 (a larger difference from the median order than the 0.04 for two differences and 10 main concepts).

We also compared the main concepts unimpaired speakers and individuals with aphasia produced at the beginning and the end of their picture descriptions. This provided qualitative information about possible differences in the global coherence of the picture descriptions of both groups.

Results

Unimpaired speakers showed on average a DiO ratio of 0.08 (SD: 0.12). In more descriptive terms this means that unimpaired participants produced on average 8.14 main concepts with about 2 differences from the median concept order we established. On an individual level we observed that 98% of the unimpaired participants produced between 0 and 6 differences (median: 1) from the median concept order.

Results of single case statistics (Crawford et al., 2006) showed that nine individuals with aphasia produced a significantly higher DiO ratio than the unimpaired participants (DiO $\geq$ 0.33; $p<.03$). Seven of these participants were amongst those participants who also produced significantly fewer main concepts and one significantly more non-main concepts than the unimpaired participants.

The remaining 41 individuals with aphasia showed no significant differences from the mean DiO ratio of unimpaired speakers (DiO< 0.29; $p>.05$).

Qualitative analysis showed that the majority of unimpaired participants (83%) produced main concepts about the CAT, the GIRL and the MAN in the first three positions of their picture description. In contrast, significantly fewer (52%) individuals with aphasia who produced a main concept about each of these entities, mentioned them within the first three positions of their description (Fisher exact-test: z = 2.64, p= .004; see Figure 4).

The main concept "*Any mention of the DOG"* appeared to be predominantly responsible for this observed difference. Most unimpaired subjects who produced a concept about the DOG produced it in fifth or sixth position (55%). Only 26% of individuals with aphasia who produced a main concept about the DOG, produced it in the same position. Instead, 42% of individuals with aphasia placed this concept in the second or third position of their picture description. For example, 71% of unimpaired speakers produced a concept about a LADDER before a concept about the DOG while only 35% of the individuals with aphasia produced this same order.

In contrast, the analysis of the end of the picture descriptions showed that 90% of all unimpaired participants who produced a main concept about the FIRE BRIGADE mentioned it in the last position. Similarly, 88% of all individuals with aphasia who produced at least one main concept about the FIRE BRIGADE mentioned it at the end of their picture description (Fisher exact-test: z = 0.07, *p*=.47; see Figure 4).

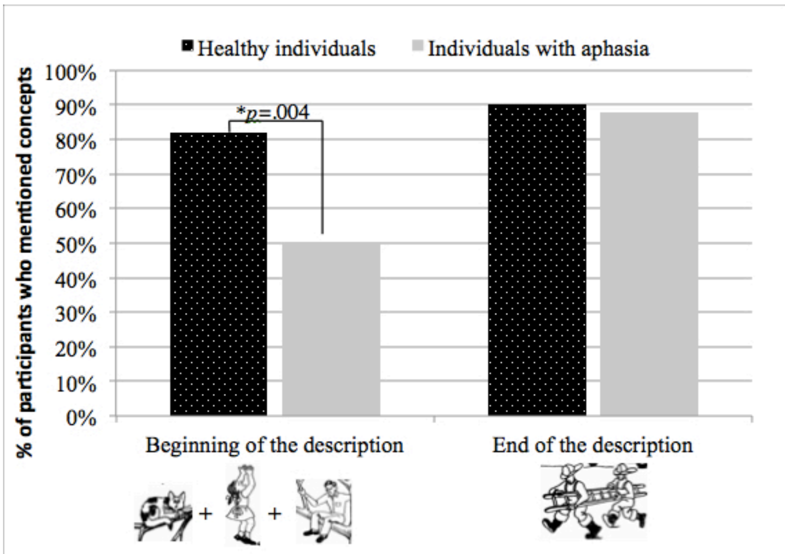

Figure 4: Proportion of participants who produced the same main concepts in the beginning and/ or end of the picture descriptions.

Discussion

In line with our hypothesis, we observed a large variability in the order of main concepts in individuals with aphasia that was especially salient in the beginning of the participants' picture description. Moreover, we identified nine individuals who showed an order of main concepts that was significantly different from unimpaired participants. We consider it possible that these order differences might be explained by underlying conceptualisation difficulties in some people with aphasia.

However, it is also possible that linguistic impairments such as word retrieval deficits could have influenced the order of concept production. For example, some of the participants with aphasia may have chosen to produce first those concepts for which they could retrieve lexical items. Consequently, in the next analysis we further investigate which factors might influence concept production.

Analysis 5: Factors influencing concept production

In order to find out more about how the nature of the impairment might influence the observed symptoms, we examined if, and in what ways, the participants' linguistic impairments (i.e., number of words, number of verbs; Verb Naming Test scores, Boston Naming Test scores) and grammatical difficulties (i.e., fluency of speech) affected production of main concepts and non-main concepts.

Method

We first examined the correlations between the number of main concepts and number of non-main concepts and measures of linguistic output: number of words, verbs and nouns for participants with aphasia and unimpaired participants (Pearson's correlations). For the individuals with aphasia we additionally calculated these correlations for our measure of how far the order of main concept in the picture description of each participant with aphasia differed from controls (Difference in order ratio; DiO).

We also examined the correlation between our three main outcome measures (#main concepts, #non-main concepts, DiO) and the participants with aphasia's ability to name nouns and verbs in the Boston Naming Test and the Verb Naming Test. Moreover, in order to tease apart the relative contribution of each measure we supplemented the correlations with linear regressions. We use Evans (1996) criteria for describing the strength of the correlations (e.g., weak: r=.20-.39; moderate: r=.40-.59; strong: r=.60-.79).

Finally, to gain information on the influence of grammatical difficulties, we conducted a one-way ANOVA to investigate if the participants' fluency of speech had a significant effect on any of the outcome measures.

Results

Unimpaired participants: Main concepts

In unimpaired participants, Pearson's correlations revealed mild to moderate correlations between the number of main concepts and the number of words, verbs and nouns (see Table 3), with no significant differences in the strength of these correlations (*Fisher z-transformation* (Fisher, 1915): $z_{\text{words vs. verbs}} = .67$, p= .25; $z_{\text{words vs. nouns}} = -.67$, p= .38; $z_{\text{nouns vs. verbs}} = .97$, p= .16).

Table 3: Mean, standard deviation and intercorrelations of the number of main concepts and number of words, verbs and nouns for unimpaired participants

	# non-main concepts r	word r	verbs r	nouns r
Number of main concepts	.32*	.42*	.30*	.47**
Number of non-main concepts		.70***	.58***	.62***
Number of words		--	.86**	.87**
Number of verbs			--	.71**
Number of nouns				--

*** *p*<. 001; ** *p*<. 01; **p*<. 05

The number of non-main concept statements was also strongly correlated with the overall number of words, verbs and nouns in the participants' picture descriptions (see Table 3). In other words, unimpaired subjects who produced generally longer picture descriptions were more likely to produce more non-main concept statements. Critically however, the size of these correlations was mainly driven by one unimpaired subject who appeared to be an outlier and produced the highest number of non-main concepts and words in the sample. If this participant is removed from the analysis the correlation coefficients dropped substantially and the correlation between the number of non-main concept statements and verbs was no longer significant ($r_{\text{non-main concepts \& words}} = .37$, p=.010, $r_{\text{non-main concepts \& verbs}} = .25$, p=.082 and $r_{\text{non-main concepts \& nouns}}$= .4, p=.005). Similarly, the observed correlation between the number of main concepts and the number of non-main concepts, is no longer significant, when this one participant was removed from the data ($r_{\text{main concepts \& non-main concepts}} = .23$, p=.117).

Individuals with aphasia: Main concepts

As in the group of unimpaired subjects, we found a significant moderate correlation between the number of main concepts and the number of words, verbs and nouns in the picture descriptions of participants with aphasia (see Table 4). Moreover, our results showed a moderate correlation between the number of main concepts individuals with aphasia produced and their verb naming.

Table 4: Intercorrelations between outcome measures for individuals with aphasia

r =	# non-main concepts	DiO-ratio	words	verbs	nouns	BNT	VNT
Number of main concepts	.39**	-.06	.52***	.55***	.49***	.26	.42**
Number of non-main concepts	--	.31*	0.84***	.70***	.64***	-.011	-.013
Difference in order ratio (DiO ratio)		--	0.11	.07	.09	-.32*	.30*
Number of words			--	.84***	.83***	-.01	-.09
Number of verbs				--	.67***	-.06	-.01
Number of nouns					--	.11	.14
Boston Naming Test						--	.63***
Verb Naming Test							--

*** p<. 001; ** p<. 01; *p<. 05

Given the high intercorrelations between many of the measures, we carried out linear regressions to further investigate the influence of the measures when shared variance is accounted for. In order to prevent multicollinearity, we only included variables with a sufficiently low intercorrelation (r<.80, Hutcheson & Sofroniou, 1999). Thus, we ran one model including number of words (but not number of verbs and number of nouns), and a second including number of nouns and verbs (but not number of words). All models included the Verb Naming Test, Boston Naming Test, number of non-main concepts and DiO ratio as predictors.

Production of a larger number of verbs or words as well as high VNT score were significant predictors of a higher number of main concepts. Hence, two measures of verb production, the VNT and the number of verbs, appear to be the best predictors for the number of main concepts in the picture descriptions of individuals with aphasia (see Table 5).

Table 5: Results of linear regressions to identify predictors for the number of main concepts in individuals with aphasia

	B	SE B	*ß*	t	p
Model 1 (Nouns & Verbs): R^2 = .423, *p*<.001					
#verbs + #nouns +VNT + BNT + #non-main concepts + DiO ratio					
#verbs	.090	.035	.45	2.61	.012*
#nouns	.012	.027	.07	.432	.67
VNT	.122	.043	.40	2.81	.007**
BNT	.005	.017	.04	.268	.79
#non-main concepts	.07	.133	.09	0.52	.61
DiO ratio	.03	1.29	.003	0.02	.98
Model 2 (Words): R^2 = .431, *p*<.001					
#words + VNT + BNT + #non-main concepts + DiO ratio					
#words	.015	.005	.62	3.00	.004**
VNT	.151	.042	.50	3.58	<.001***
BNT	-.006	.018	-.05	-.330	.743
#non-main concepts	-.061	.163	-.08	-.375	.709
DiO ratio	.251	1.29	.02	.193	.848

****p* < .001; ***p*<.01; **p* < .05

Individuals with aphasia: Non-main concepts

The number of non-main concept statements in the participants' picture descriptions was also strongly correlated with the number of words, verbs and nouns. In contrast to unimpaired participants however, these correlations were not driven by one individual.

Once again, we carried out linear regressions, including the same predictors as for the main concept analysis above, but with main concepts replacing non-main concepts. Results showed that a high number of non-main concept statements in the participants' picture descriptions were predicted by a higher DiO ratio and production of more words or more verbs and nouns (see Table 6).

Table 6: Results of linear regressions to identify the best predictors for the number of non-main concepts in individuals with aphasia

	B	SE B	*ß*	t	p
Model 1 (Nouns & Verbs): R^2 = .58, *p*<.001					
# nouns + #verbs + BNT + VNT + #main concepts + DiO ratio					
#nouns	.072	.029	.32	2.48	.017*
#verbs	.119	.039	.43	3.08	.004**
BNT	.006	.021	.03	.283	.77
VNT	-.064	.053	-.16	-1.21	.23
#main concepts	.091	.174	.07	0.52	.61
DiO ratio	2.99	1.41	.21	2.12	.039*
Model 2 (Words): R^2 = .73, *p*<.001					
#words + BNT + VNT + #main concepts + DiO ratio					
#words	.028	.003	.84	8.87	<.001***
BNT	-.010	.016	-.06	-.60	0.55
VNT	.024	.044	.06	0.54	0.59
#main concepts	-.052	.139	-.04	-0.38	0.71
DiO ratio	2.92	1.11	.21	2.62	.012*

****p* < .001; ***p*<.01; **p* < .05

In a further analysis, we found no significant correlations between the number of statements falling in the "marginally relevant" subcategory of non-main concepts and either the number of main concepts or the DiO-ratio ($r_{marg.relevant\ \&\ \#MC}$ =.2, *p*=.16 ; $r_{marg.relevant\ \&\ DiO}$ =.21; *p*=.130).

Individuals with aphasia: Order

We found significant correlations between the participants with aphasias' DiO ratio and the number of non-main concepts they produced in their picture description, their BNT score and VNT score (see Table 4, earlier). Nevertheless, linear regression (see Table 7) revealed a high number of non-main concepts as the only significant predictor for a higher DiO ratio.

Critically however, the linear regression model only reached significance in the model with number of words as a factor rather than numbers of nouns and verbs. Moreover, it is interesting to note that the amount of the variance explained for the DiO ratio was much smaller than for the linear models examining predictors of the participants' number of main concepts and non-main concepts.

Table 7: Results of linear regressions to identify best predictors of the difference-in-order-ratio in individuals with aphasia.

	B	SE B	*ß*	t	p
Model 1 (Nouns & Verbs): R^2 = .12, *p*=.074					
# nouns + #verbs + BNT + VNT + #main concepts + #non-main concepts					
#nouns	.001	.003	.04	0.22	.83
#verbs	-.001	.004	-.29	-1.31	.20
BNT	-.003	.002	-.23	-1.33	.19
VNT	-.003	.006	-.10	-0.54	.59
#main concepts	.0003	.018	.004	0.02	.98
#non-main concepts	.031	.015	.44	2.12	.039*
Model 2 (Words): R^2 = .16, *p*=.025*					
#words + BNT + VNT + #main concepts + #non-main concepts					
#words	-.001	.001	-.47	-1.73	.09
BNT	-.002	.002	-.16	-0.95	.35
VNT	-.005	.006	-.17	-0.87	.39
#main concepts	.003	.018	.04	0.19	.85
#non-main concepts	.046	.018	.65	2.62	.012*

***$p < .001$; **$p<.01$; *$p < .05$

Individuals with aphasia: Fluency

Finally, we examined the effect of rated fluency on performance. Non-fluent speakers produced significantly fewer main concepts than fluent individuals with aphasia (t(98) =-2,48: *p*=.017). However, when we performed an ANCOVA analysis in which the severity of impairment represented by the WAB-AQ was added as a covariate, the significant effect of fluency disappeared (post-hoc Tukey's HSD test: p=.112).

Similarly, there was not a significant effect of fluency for the number of non-main concepts or DiO ratio with severity of impairment (WAB-AQ) as a covariate (non-main concepts: $F(1,1) = 1.478$, $p = .23$; DiO-ratio: $F(1,1) = 0.539$, $p = .46$).

Discussion

Unimpaired participants

Perhaps unsurprisingly, for unimpaired participants, the more words, nouns or verbs a participant produced, the more main concepts and non-main concepts were produced. Due to the naturally high intercorrelations between the number of words and the number of nouns and verbs, it seems likely that verbs and nouns were a major driver of the effect of the number of words.

Individuals with Aphasia

Similar to the unimpaired participants, we found that individuals with aphasia who produced more words, nouns, and verbs were more likely to produce more main concepts. Again, high intercorrelations suggest that the number of verbs and nouns were strongly driving the overall effect of words.

Moreover, our results showed that production of a large number of non-main concepts was associated with a larger difference in the order in which concepts were produced relative to the controls. Nevertheless, only two individuals produced a significantly larger number of non-main concepts in combination with a significantly higher DiO ratio. We suggest that this combination of symptoms may indicate underlying conceptualisation difficulties for these two participants with aphasia. In addition, we also identified 7 participants who produced significantly fewer main concepts in combination with significantly different DiO ratios. We suggest that for these participants, there may be an underlying difficulty in selecting the most important information within the picture and this leads to reduced speech output.

Despite the fact that, in the literature, the only patients to have been reported with conceptualisation deficits have been non-fluent/agrammatic (e.g., Marshall et al., 1993; Cairns et al., 2007), our results did not suggest any significant differences between the performance of fluent and non-fluent participants with aphasia. We will discuss this in more detail in the General Discussion.

General Discussion

This study focused on conceptualisation, which constitutes the first step of our speech production process and has been argued to be highly interlinked with language (e.g., Levelt, 1989; Slobin, 1996). Single case reports have suggested that individuals with language impairments, such as aphasia, may show discourse difficulties that point to conceptualisation deficits (Cairns et al., 2007; Manning & Franklin, 2016; Marshall, 2009). At a macrostructural level these symptoms have been suggested to include production of 1) a reduced amount of relevant information; 2) a high proportion of irrelevant information (Cairns et al., 2007; Dean & Black, 2005; Marshall et al., 1993); and, 3) sequencing errors in discourse (Manning & Franklin, 2016). This study aimed to extend the previous research by investigating if such symptoms were apparent in the picture description performance of a larger population of individuals with aphasia and to determine possible markers of impairments in macrostructural conceptualisation.

Production of relevant information

While reduced informativeness is a common feature of spontaneous speech in aphasia (e.g., Marini et al., 2011; Nicholas & Brookshire, 1995), it is also described as one of the key symptoms of people with presumed conceptualisation deficits (Cairns et al., 2007). Indeed, half of the participants with aphasia in this study produced a significantly reduced amount of relevant information, represented by a low number of main concepts (< 7 main concepts), in their picture descriptions.

Cairns (2006) suggests that people with conceptualisation impairments might have difficulties focusing on depicted events in the same way as unimpaired speakers. To conceptualise a picture for a description, we need to choose which information we talk about and which is assigned to the background. Participants who experience difficulties with this process would fail to determine the information that is central to the story they wish to tell about a picture, the result of which could be production of an arbitrary amount of information (either too much or too little). The reduced number of main ideas we observed in our study could therefore be a possible outcome of such a lack of focus which makes it harder for the participants to retrieve the information necessary to describe the depicted scene. As a result, some participants might have been unable to identify all main events and, consequently, produced fewer main concepts.

Additionally, Marshall et al. (1993) described a link between presumed conceptualisation deficits and poor verb retrieval in a verb picture naming task as well as a limited verb use in picture description. Similarly, Dean and Black (2005) reported naming deficits that were disproportionally more severe for verbs than for nouns in their single cases and suggested this was a consequence of the participants' difficulties in conceptualising verbs. While the participants in our study showed impairments in both verb and noun naming, it was only poor verb naming and a reduced number of verbs in the picture description that were significant predictors of a low number of main concepts: noun naming was not a predictor. Hence, we consider it possible that the association between main concept production and verb production could be a consequence of conceptualisation deficits underlying both symptoms.

However, while the reduction in the number of main concepts is consistent with conceptualisation impairment, there are other factors that should also be considered. First, there is the problem that spontaneous speech is commonly acknowledged to be highly variable, even in unimpaired speakers (e.g., Armstrong, 2002). Indeed, the number of main concepts in the picture descriptions of unimpaired participants in our sample varied between 3 and 10. Consequently, part of the observed variability in the number of main concepts produced by participants with aphasia could be due to this natural variability. However, few unimpaired individuals (6%) produced less than seven main concepts as opposed to 50% of the individuals with aphasia. Consequently, it is unlikely that this can fully account for our data and additional explanations for the reduced number of main concepts in aphasia have to be taken into account.

It is also probable that the reduction in main concept production could partly be caused by the participants' expressive language impairment (e.g. word finding deficits). It seems unsurprising that, in general, those unimpaired individuals and individuals with aphasia, who said less, also produced fewer main concepts. Indeed, reduced informativeness in the discourse of individuals with aphasia has been frequently described (Andreetta, Cantagallo, & Marini, 2012; Armstrong, 2000). However, it is important to note that our analysis included both verbal and non-verbal responses (e.g., pointing, gestures). So, there is at least the possibility that linguistic impairments could be compensated for through non-verbal responses. Nevertheless, none of the individuals with aphasia was specifically encouraged to use non-verbal communication. Hence, some participants with severe expressive difficulties, but intact conceptualisation, could have been reluctant to use non-verbal strategies but may have been able to convey more information if they had.

Moreover, despite the general association, it is clear that reduced verbal output, caused by more severe language impairments, does not necessarily lead to a reduction in main concept production. For example, one participant with aphasia produced a total number of 250 words and 7 main concepts, while another participant with aphasia produced only 37 words but also produced 7 main concepts. It is also important to note that we also identified five individuals with relatively mild expressive impairments (WAB-AQ >75), who, nevertheless, produced significantly fewer main concepts than unimpaired controls. Consequently, while expressive language impairments might seem like an obvious explanation, we suggest that the reduced number of main concepts cannot be fully explained by linguistic deficits, therefore, supporting our assertion that (nonlinguistic) conceptualisation deficits may contribute to this pattern of performance. We suggest that for future research, an approach that takes non-verbal information into account is preferable to an informativeness measure that focuses on purely verbal measures (e.g., Marini et al., 2011: lexical content; Nicholas & Brookshire, 1995: verbally expressed main concepts).

Consistent with the 'Thinking for Speaking' account, Dipper et al. (2005) propose that language impairment might reduce linguistic constraints resulting in individuals with aphasia having problems preparing messages for speech production in a "spiral of impairment". While we do not dispute that this is a possible account for the reduced informativeness we observed in some participants, it is striking that half of the individuals with aphasia were not significantly different from the controls in the number of main concepts produced. Under a spiral of impairment account, one might have thought that most people with aphasia should have presented with symptoms related to reduced linguistic constraints on microstructural planning (e.g., inappropriate perspective changes). Consequently, we would argue that the reduction of linguistic constraints in aphasia cannot alone account for the variety in the participants' macrostructural performance that we observed in this study. Nevertheless, we acknowledge that such symptoms may be difficult to detect in the description of a complex picture, as used here.

Importantly, however, some of the participants whose number of main concepts lay with the range of unimpaired controls, produced the highest numbers of non-main concepts (less relevant information), a pattern which is also associated with presumed conceptualisation deficits (Cairns et al., 2007; Marshall et al., 1993).

Production of irrelevant information

A preponderance of irrelevant or excessively detailed information has been repeatedly reported in single case studies of individuals with presumed conceptualisation impairments (Cairns et al., 2007; Dean & Black, 2005; Marshall et al., 1993). Consequently, we hypothesised that people who had difficulties processing and identifying depicted main events, would produce relatively more irrelevant information (i.e., non-main concepts) in their picture descriptions.

Indeed, our results showed that individuals with aphasia produced significantly more statements that were less central to the depicted event than unimpaired participants. Cairns et al. (2007) hypothesised that this might suggest that some participants with aphasia have difficulties in staying focused on relevant aspects of the target picture and hence appropriately assigning this information to the foreground and background of their descriptions. Our data supports this idea. Individuals with aphasia produced significantly more statements like "the tree has long skinny branches" and "the firemen got boots on" than unimpaired participants. We assume that unimpaired speakers backgrounded these details and therefore did not mention them in their descriptions. In contrast, those individuals with aphasia who mentioned such statements might have experienced difficulties in distinguishing key information from background information.

Importantly, we identified two participants with aphasia who produced a significantly reduced number of main concepts in combination with a significantly increased number of non-main concepts (AphasiaBank ID: ACWT11a & kansas10a). These participants were diagnosed with Wernicke's aphasia and conduction aphasia respectively. Both participants provided relatively fluent and extensive picture descriptions characterised by frequent word finding difficulties.

Given that both a reduced number of main concepts and a large number of non-main concepts have been associated with conceptualisation difficulties (e.g., Dean & Black, 2005), it seems particularly likely that the observed discourse deficits of these two participants were underpinned by conceptualisation deficits. A more detailed investigation of, for example, their non-verbal event-processing abilities would be particularly interesting to confirm this hypothesis.

In contrast to previous reports that associated conceptualisation deficits with a predominantly agrammatic symptom pattern (e.g., Marshall et al., 1993; Marshall, 2009), both of these participants were diagnosed with a fluent variant of aphasia. When we compared the number of non-main concepts produced between fluent and non-fluent speakers (who were likely to be predominantly agrammatic), we found no reliable difference. This seems to suggest that grammatical impairments had no, or only limited, influence on the participants' non-main concept production and does not appear to serve as a reliable predictor for conceptualisation deficits in this sample.

Although we propose that the relatively large proportion of irrelevant information produced by the participants with aphasia in our study is consistent with conceptualisation difficulties, we also have to acknowledge that the relatively large variability in the number of non-main concepts we observed in unimpaired individuals (between 0 and 11 non-main concepts) casts doubt on this claim.

Relatively large amounts of irrelevant information were also previously described in unimpaired speakers by Graham, Patterson, & Hodges (Graham, Patterson, & Hodges, 2004) and was hypothesised to reflect natural variability in picture descriptions (i.e., Cookie Theft). However, we think it probable that in picture description some participants feel pressured to produce very detailed descriptions in order to perform the task especially well. The comparatively large correlation we observed between the unimpaired participants' number of non-main concepts and the number of words and verbs in their descriptions supports this idea. We observed a similarly large correlation in the participants with aphasia. The AphasiaBank testing protocol did not include practice items for the required picture description response. Consequently, we consider it possible that participants interpreted the task differently. In some cases that might have resulted in a more detailed description. Statements like "my wife's son is a fireman" (BU09a; fluent; conduction aphasia), seem to support the hypothesis, that some participants tried to relate the story more to their own life and did not entirely adhere to the task. Nevertheless, we suggest natural variability, different task interpretations or the lack of time restrictions in the picture descriptions cannot fully account for the large number of non-main concepts in aphasia. This is because, in contrast to unimpaired speakers, a high number of non-main concepts were additionally predicted by a large DiO (Difference-in Order) ratio in the speakers with aphasia. We suggest that this association between non-main concept production and difficulties with order is the result of them both having the same underlying cause: difficulties in conceptualisation. We discuss this in more detail below.

Sequencing of concept production

The participant with presumed conceptualisation deficits reported by Cairns et al. (2007) produced the individual entities of a single event picture in an order that was different from unimpaired participants. Consequently, we hypothesised that conceptualisation disorders in aphasia might be represented in a main concept order that differs from the main concept order of unimpaired speakers.

We indeed observed substantial variability in the order of main concepts produced by individuals with aphasia. This suggests that some people with aphasia might have had difficulties in ordering main concepts in the same way as unimpaired individuals and supports Manning and Franklin's (2016) assertion that examination of the order of information is a valuable addition to discourse analyses in aphasia. However, past studies have only investigated participants' ability to form coherence linguistically (e.g., use of pronouns; Marini et al., 2011). Investigating the order of main concepts made it possible for us to evaluate coherence even when the participants were unable to verbally link their ideas (i.e. main concepts) chronologically or causally link successive information. As an example, one participant with severe expressive impairments conveyed links between individual main concepts as follows: "this here {points: cat} and {slides finger up the tree}. and man {slides finger up the tree}.

We suggest that the large variability in the main concept order of some participants with aphasia might, yet again, reflect a problem in weighing the importance of the depicted events as well as problems conceptualising links between them. Cairns et al. (2007) proposed that such an impairment could lead the participants to treat every entity as equally important and result in an almost arbitrary order. This idea is supported by our finding that an increased number of non-main concepts was a significant predictor of larger order differences.

Another important factor could be that the initiating event for the "Cat Rescue" picture (e.g., the cat climbed the tree and is stuck) needs to be inferred and therefore relies heavily on conceptualisation processes. Capilouto and colleagues (2006) observed that participants with aphasia produce fewer information units in their descriptions of a single event picture (such as the Cat Rescue scene) than a sequential picture stimulus. They argue that the additional requirement to infer a sequence and links between individual events could account for this observation. Similarly, we suggest that an impaired ability to make inferences about the picture could also explain the large variability in the beginning of the description of some individuals with aphasia. In contrast, the most likely ending of the story – “The fire brigade comes” - is depicted as currently happening in the picture and does not need to be inferred. This might make it easier for the participants to conceptualise this event and place it in the narrative.

The structure of the target picture itself could have also affected the order of main concepts the participants produced. For example, the spatial organisation of the Cat Rescue picture might have influenced the order in which people described the depicted events. Chatterjee, Maher, & Heilman (1995) show that even unimpaired participants are more inclined to associate entities on the left side of a picture with the subject position. Although Chatterjee and colleagues’ study focussed on sentence comprehension rather than picture description, it is possible that some participants with aphasia, when encountering difficulties identifying the relationship between individual entities, may follow a purely spatial (left to right) approach to ordering the events in their picture descriptions.

The visual salience of the individual entities could have also affected the order of main concept production. Entities that are in a prominent position of the picture (e.g., central) are likely to draw the most attention and hence are likely to be selected as a starting point for the picture description (Black & Chiat, 2003, p. 195ff). This might explain the large variety we observed in the beginning of the picture descriptions of the participants with aphasia. We think it possible that difficulty identifying the importance of each entity in the depicted events and/or the relation between entities, may result in a greater influence of visual saliency. Hence, they might have chosen to start their description with a statement about the DOG, just because it is very salient entity due to its animate nature and depicted in a central position. The role of visual factors in picture description and their interaction with conceptualisation impairments may be a fruitful area for further research.

Importantly, the lack of correlation between the order of main concepts and the number of words the participants produced in their picture description suggests that the ability to establish a meaningful order of main concepts is independent from the ability to produce speech in aphasia. Similar results were reported by Manning and Franklin (2016), who observed that temporal sequencing errors were independent from noun naming and hence, from the severity of the participants' expressive language impairments. Hence, our results support Manning and Franklin's assertion that the order of main concepts could be an especially valuable addition to common discourse analysis measures and we suggest that order sequencing impairments could be a possible predictor of conceptualisation deficits in aphasia.

While there was no overall relationship between language impairment and production of main concepts in a 'typical' order, it is still possible that some participants might have been unable to access or retrieve the words that were required to describe a specific part of the scene. Hence, they might have mentioned the main concepts in an order in which they were able to retrieve them with little regard of their contribution to the depicted scene. For example, individuals with aphasia were more likely to produce a concept about the DOG very early (3^{rd} or 4^{th} position) in their picture description than unimpaired participants (DOG mentioned on average in 5^{th} position) and the word DOG is highly familiar and high in frequency. Consequently, DOG might have been easier to retrieve than the names of other entities like LADDER, which 71% of unimpaired participants but only 35% of individuals with aphasia mentioned before DOG. Nevertheless, given that conceptualisation is a precursor of lexical access, it seems unlikely that participants would disregard the temporal and/or causal links they might have conceptualised. If, however, the participants have difficulties to conceptualise these links, then starting with statements about the entities they can retrieve seems a plausible strategy.

Clearly further research is necessary to gain more detailed information on the factors underpinning the observed variability in the order of production of main concepts individuals with aphasia.

Summary and future directions

In summary, this study aimed to investigate possible conceptualisation deficits in individuals with aphasia by analysing the number, content and order of concepts produced in a picture description. Our analysis provides further evidence for findings of previous single case reports that some individuals with aphasia produced less relevant information and more marginally relevant information than unimpaired speakers (e.g., Cairns et al., 2007; Dean & Black, 2005) and seem to have difficulty appropriately ordering the concepts produced (Manning & Franklin, 2016). Our study shows that these symptoms can also be found in a large, randomly selected group of individuals with aphasia. Therefore, we suggest they can be used as markers of a possible nonlinguistic conceptualisation impairment in aphasia. Our findings further suggest that conceptualisation deficits might be more common in aphasia than previously reported.

Future research should focus on further investigations of the conceptualisation abilities of participants who show one or more of the above mentioned symptoms. These tasks could include, for example, non-verbal event-processing tasks (e.g., Marshall et al., 1993; Cairns et al. 2007; Byng et al., 1994) to enable confirmation of the hypothesis of underlying conceptualisation deficits.

Overall, our results provide evidence that the concept analysis we performed, can inform our understanding of conceptualisation skills in aphasia and will constitute a valuable complement to other discourse measures (e.g., Armstrong, 2000; Armstrong et al., 2013; Marini, 2012). We particularly support Manning & Franklin's (2016) proposal that the analysis of the order in which participants with aphasia produce their main concepts is an especially important addition to traditional spontaneous speech analysis approaches. In our study, the order of main concepts was not influenced by any linguistic parameters and may therefore serve as a valuable pointer for conceptualisation deficits which are independent from an individual's language impairment.

Conclusion

In 'Alice in Wonderland' the king suggests to "*Begin at the beginning […] and go on till you come to the end: then stop"* (Carroll, 1920, p. 182). Our study showed that following this advice could be hard for some individuals with aphasia. The production of a reduced number and/ or unusual order of main concepts as well as a large number of non-main concepts are argued to be possible key symptoms of conceptualisation disorders in aphasia. We propose that they may be used to identify individuals who should undergo further testing of their conceptualisation skills, in order that specifically targeted language therapy can be provided to help these people to tell their story from beginning to end.

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Appendices

Appendix A: Demographics of individuals with aphasia (WAB=Western Aphasia Battery (Kertesz, 1982); BNT = Boston Naming Test (Kaplan et al., 1883) VNT= Verb Naming Test (Cho-Reyes & Thompson, 2012)

ID	Aphasia Bank ID	Gender	Age	Diagnosis	Fluency	WAB-AQ (max. 100)	Boston Naming Test (n=60)	Verb Naming Test (n=22)
1	ACWT01a	F	69.09	BRO	nfl	63.9	50	22
2	ACWT03a	M	68.01	BRO	nfl	69.3	56	21
3	ACWT05a	M	75.06	BRO	nfl	57.7	55	8
4	ACWT11a	M	61.07	WER	flu	48.9	44	13
5	ACWT12a	F	83.01	CON	nfl	79.5	58	21
6	Adler02a	M	69.08	CON	flu	74.9	46	7
7	BU01a	M	62.06	ANO	flu	85.7	59	21
8	BU09a	M	78.05	CON	flu	65.3	31	16
9	elman02a	F	81.11	BRO	nfl	61.7	33	7
10	TCU05a	F	70.04	ANO	flu	92.0	60	22
11	whiteside02a	F	74.06	CON	flu	60.7	22	5
12	adler25a	M	66.02	BRO	nfl	77.6	60	18
13	elman06a	F	76.09	BRO	nfl	45.5	12	2
14	adler09a	F	41.07	ANO	flu	92.8	52	21
15	kansas21a	M	60.09	CON	flu	77.2	58	20
16	kansas10a	M	77.00	CON	flu	61.4	20	19
17	scale22a	M	73.07	ANO	flu	90.4	58	22
18	williamson11a	F	64.08	BRO	nfl	69.0	45	18
19	tap11a	F	62.07	BRO	nfl	58.1	20	9
20	star03a	M	85.07	ANO	flu	75.1	26	4
21	scale08a	M	72.08	ANO	flu	87.9	50	18
22	tucson08a	F	56.06	CON	flu	73.4	54	14
23	tucson01a	M	76.10	ANO	flu	92.8	60	22
24	elman14a	F	76.03	CON	flu	65.7	37	7
25	kempler03	M	64.05	BRO	nfl	60.7	4	17
26	garrett01a	F	76.07	WER	flu	52.4	14	4

27	MSU1a	M	79.09	ANO	flu	89.6	56	19
28	MSU08a	F	75.05	CON	flu	60.5	30	5
29	MSU05a	M	72.09	BRO	nfl	68.2	37	6
30	Scale23a	F	57.05	CON	flu	64.5	46	18
31	kurland13a	M	55.00	BRO	nfl	54.0	42	11
32	scale01a	M	78.03	BRO	nfl	52.5	30	7
33	scale10a	M	44.07	BRO	nfl	63.5	56	15
34	scale11a	F	90.07	WER	flu	65.9	27	10
35	scale13a	M	70.02	BRO	nfl	70.1	46	10
36	fridriksson07a	F	78.00	ANO	flu	92.6	60	21
37	williamson19a	F	52.07	BRO	nfl	69.4	53	12
38	williamson10a	M	72.00	NCL	flu	95.2	60	22
39	whiteside14a	F	42.06	BRO	nfl	71.8	58	14
40	tucson15b	M	79.00	CON	flu	57.8	42	13
41	thompson11a	F	79.03	ANO	nfl	81.4	57	8
42	thompson07a	M	70.00	BRO	nfl	93.4	60	20
43	thompson04a	F	79.06	ANO	flu	74.4	53	14
44	kurland09a	F	80.06	TCS	flu	79.9	48	16
45	fridriksson06a	M	50.04	BRO	nfl	49.0	44	10
46	kansas07a	F	77.04	ANO	flu	96.1	60	22
47	adler03a	F	78.04	ANO	flu	93.8	60	22
48	ACWT07a	M	61.05	ANO	nfl	95.0	60	21
49	ACWT02a	F	51.01	BRO	nfl	74.6	56	22
50	kurland07a	F	70.06	ANO	flu	83.0	58	9

Appendix B: List of 57 phrases that have been identified as concepts and percentage of unimpaired participants who mentioned each of these concepts

#	Concepts	%
1	The man climbed/ is in the tree	98
2	Man wants to get the cat [*plausible motivation to climb the tree]	74
3	Man used ladder [Man/ Ladder *plausible action]	54
4	The man comes	24
5	The man is very upset	2
6	The man looks foolish	4
7	The situation messed the father up	2
8	The man thinks he is a squirrel	2
9	The man called the girl	2
10	The girl is concerned [*negative emotional state of the girl]	38
11	The girl is calling the cat	8
12	The girl wants the cat to come down [*motivation of the girl]	30
13	The girl has a cat	4
14	The girl is standing there [*plausible location]	32
15	The girl was playing outside [*plausible action]	34
16	The girl has a bike	12
17	The girl gets help (e.g., calling the father)	30
18	The girl is happy	2
19	The girl runs home	2
20	The girl found her dad	2
21	The girl has a dog	2
22	The girl got a ladder	2
23	The girl came in	2
24	The girl came back out	2
25	The cat climbed/ is in the tree	96
26	The cat is a family cat	2
27	The cat wanted to get the bird [*motivation of the cat]	38
28	The cat was following the girl	2
29	The dog is barking [*making noise]	52
30	The dog was not successful n helping the cat	2
31	The dog is excited [*motivation of the dog]	20
32	The dog settles down	2
33	The dog comes	16
34	The dog will walk away	2
35	The dog's barking alerted the neighbours	2
36	The dog is trying to climb the tree	2

37	The dog looks up the tree	2
38	The fire brigade is coming [*arrival at the scene]	94
39	The fire brigade rescues them [*help/rescue]	96
40	The fire brigade is trained in ladder rescues	2
41	The fire brigade brings a ladder	68
42	The fire brigade climbed up the tree/ up the ladder/ got up the tree	6
43	The fire brigade deals with the dog	4
44	Someone must have called the fire brigade	66
45	The ladder is lost	72
46	The ladder is there	4
47	They didn't use the ladder	2
48	The bird is singing	14
49	The bird is sitting there [*location]	16
50	The bird would fly away	2
51	The bird is just acting like a bird	2
52	The bird doesn't care [*mental state]	6
53	The people come over	2
54	The people want to help the cat	2
55	Someone must have seen the dilemma	4
56	The mother is looking out of the window	2
57	The mother is back in the house	2

Appendix C: Calculating the difference-in-order (DiO) ratio

We generated a matrix to compare the main concept order of each individual with aphasia to the median main concept order (see Table C).

Table 1: Comparison matrix to evaluate the extent to which an individual concept order differed from the median concept order of unimpaired individuals.

Example		Median Concept Order									
Individual Participant Concept Order	Median Concept Order	A	B	C	D	E	F	G	H	I	J
H	A	-	1	0	1		0		0	0	1
I	B	-	-	0	0		0		0	0	1
F	C	-	-	-	1		0		0	0	1
C	D	-	-	-	-		0		0	0	1
	E										
A	F	-	-	-	-		-		0	0	1
	G										
D	H	-	-	-	-		-		-	1	1
B	I	-	-	-	-		-		-	-	1
J	J	-	-	-	-		-		-	-	-

The top row of the matrix represents the median main concept order in the form of letters from A to J. The actual concept order of the individual with aphasia was represented in the first column of the matrix. In the example illustrated in Table 1 the participant produced concept H before concept I followed by concept F, C, A, D, B, and J. If a main concept was missing in an individual's picture description (here: concept E and G) the rows and columns of the corresponding concepts were disregarded for the analysis (e.g., see shading of columns and rows for concepts E and G in Table 1). The second column represented once again the concepts in the median concept order from unimpaired participants and was used to score order. We identified differences in the order of main concepts by comparing the main concepts that should have followed a particular main concept (e.g. A) according to the median order (B, C, D, E, F, G, H, I, J) with the main concepts that actually followed it in the participant's picture description (see example in Table 1: D, B, J). To indicate that an individual with aphasia produced concept

A before concept B, we entered a "1" in the cell that corresponded to the intersection of A in the second column (concept produced by individual with aphasia) and with the B in the first row (concept that should be produced after A, according to the median concept order). The participant in the Table 1 example produced concept A before concept B. Hence, a "1" was entered in the corresponding cell "AB" (see Table 1, shaded green).

When we found that a participant produced a specific main concept (e.g., A) in a different position relative to the median main concept order (e.g., individual produced A after C, see example Table 1) we entered a "0" in the corresponding cell (see Table 1; cell "AC" shaded red). The example in Table 1 illustrates this further. Here, the participant produced the concept A before B, D and J (coded with "1" in cells AB, AD, AJ; see Table 1; green numbers), but after the concepts C, F, H and I (coded with "0" in cells AC, AF, AH, AI; see Table 1; red numbers).

This matrix enabled us to calculate a *difference-in-order ratio* for each participant in this study. This ratio was calculated as follows:

1) Total number of possible differences in order (based on the number of main concepts that were produced)
2) Total number of observed differences (corresponding to number of "0"s in the matrix)
3) Difference-in-order ratio = $\frac{\text{Total number of actual differnces}}{\text{Total number of possible differnces}}$

The closer the difference-in-order ratio was to 1.00, the larger the participant's deviation from the median concept order of unimpaired speakers.

The participant in the Table 1 example produced eight different main concepts (A, B, C, D, F, H, I, J) which resulted in a total of 28 possible differences in order (corresponding to the total number of cells that can be filled in the matrix.) The number of actual differences that occurred in the participant's picture description was 16 (corresponding to number of zeros in the matrix). The difference-in-order ratio for this particular participant in Table 1 is hence: 16/28 = 0.57.

CHAPTER 3

"I wonder why it's leaking" - What Cookie Theft picture descriptions tell us about conceptualisation processes in primary progressive aphasia.[2]

[2] Submitted for publication: Hameister, I., Foxe, D., Hodges, J., Piguet, O. & Nickels, L. **"**I wonder why it's leaking" - What Cookie Theft picture descriptions tell us about conceptualisation difficulties in primary progressive aphasia. *(submitted September 2018)*

Abstract

Individuals with primary progressive aphasia (PPA) have been found to produce less content in their speech and have difficulties linking this content coherently. However, it is not clear whether all PPA variants show these symptoms nor which mechanisms might underpin them.

To address this gap in the literature, we analysed the Cookie Theft picture descriptions of 60 people with PPA (20 nonfluent variant (nfv)PPA, 20 semantic variant (sv)PPA, 20 logopenic variant (lv)PPA) and 20 unimpaired controls. We hypothesised that some PPA participants would show difficulties understanding the depicted scene and/or maintaining attention on important elements (i.e., conceptualisation deficits) represented by reduced essential information (main concepts), increased non-essential information (non-main concepts) and atypical main concept order.

40% of participants (n=24; 6 nfvPPA, 12 svPPA, 6 lvPPA) produced significantly fewer main concepts and/or omitted central concepts that were mentioned by all unimpaired controls. Moreover, 20% (n=12; 6 svPPA, 6 lvPPA) produced an unusually large proportion of non-main concepts. Surprisingly, the Cookie Theft picture did not elicit a consensus for main concept order in unimpaired controls. Nonetheless, three PPA individuals (1 nfvPPA, 2 lvPPA) showed an atypical main concept order that was not observed in any unimpaired control.

All three of our hypothesised symptoms of conceptualisation impairment were observed in at least one participant with PPA. However, no PPA participant showed all three symptoms. While some of these symptoms may be the result of linguistic impairment, we suggest that impairments in event processing, conceptual-semantic processing, working memory and attention may also underpin the symptoms observed. Overall, our results contribute to a better understanding of conceptualisation difficulties in PPA that will help to develop better targeted and more effective interventions.

Introduction

In order to communicate, we need to narrow our multitude of thoughts down to a simple structure that can be expressed in a sentence. The process that enables us to perform this highly complex task is commonly known as *conceptualisation* (Levelt, 1989). While it is clear that language and conceptualisation are highly interlinked (e.g., Slobin, 1996), surprisingly little is known about the interaction between conceptualisation and language impairments.

Levelt (1989) describes conceptualisation as the first stage of speech production. The main goal of the conceptualisation process is to prepare a preverbal message that can be further processed in the formulator (Levelt, 1989). Levelt proposes two steps to transform our thoughts into a schematized preverbal message: *macroplanning* and *microplanning*.

During macroplanning we form a speaking intention: What do we want to say? We decide which information we need to select and how it should be ordered to facilitate the listeners' understanding of our speaking intention (Levelt, 1989). During *microplanning* we 'fine-tune' our preverbal message into a schematized, propositional structure that can be verbalised (Levelt, 1989): we choose an appropriate perspective and establish a linguistic structure for our message (e.g., assign thematic roles).

Macrostructural deficits in aphasia

While unimpaired speakers achieve this highly complex conceptualisation process with ease and usually without awareness, speakers with acquired language impairments (e.g., stroke-induced aphasia and primary progressive aphasia) can experience considerable difficulties with conceptualisation as previously reported in the 'Thinking for Speaking' literature (e.g., Slobin, 1996; Cairns, Marshall, Cairns, & Dipper, 2007; Dipper, Black, & Bryan, 2005) The 'Thinking for Speaking' theory argues that a specific type of thinking, that is highly influenced by linguistic constraints, is necessary to conceptualise speech production (Slobin 1996). When access to linguistic information is impaired, as for example in people with acquired language impairments, conceptualisation processes may be affected as well (Black & Chiat, 2000).

Previous studies have most commonly reported symptoms of possible conceptualisation deficits at the sentence level and have therefore associated these difficulties with microstructural planning processes (e.g., Cairns et al., 2007; Dipper, Black, & Bryan, 2005; Marshall, 2009). However, similar symptoms have also been reported in more complex discourse and associated with macrostructural processes like information selection and sequencing (e.g., Levelt, 1989; Linnik, Bastiaanse, & Höhle, 2016; Hameister & Nickels, 2018)

We summarise three symptoms reported in the literature which might be associated with possible conceptualisation difficulties at the macrostructural level:

1) Reduced informativeness/omission of essential information (Cairns et al., 2007; Hameister & Nickels, 2018; Linnik, Bastiaanse, & Höhle, 2016; Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, & North, 1983)
2) A large proportion of irrelevant information, such as descriptions of details (Byng, Nickels, & Black, 1994; Cairns et al., 2007; Hameister & Nickels, 2018; Marshall, Pring, & Chiat, 1993)
3) Temporal and causal sequencing difficulties (Cairns et al., 2007; Carragher, Sage, & Conroy, 2015; Hameister & Nickels, 2018; Manning & Franklin, 2016)

Perhaps unsurprisingly, reduced informativeness is very common in the discourse of individuals with aphasia (e.g., Armstrong, 2000; Marini, Andreetta, Tin, & Carlomagno, 2011) and most authors have attributed this to the participants' language impairment (e.g., Andreetta, Cantagallo, & Marini, 2012; Ulatowska et al., 1983). Nevertheless, some authors have also associated a reduced amount of essential information in discourse (i.e., a reduced number of main concepts) with event processing (e.g., difficulties identifying events) or conceptualisation deficits (difficulties weighting the importance of information) in some individuals with aphasia (Cairns et al., 2007; Dean & Black, 2005; Dipper et al., 2005; Hameister & Nickels, 2018; Marshall et al., 1993). Hence, reduced informativeness alone is not sufficient to clearly distinguish between possible conceptualisation impairments and other possible explanations (e.g., word retrieval deficits).

Cairns et al. (2007) and Dean and Black (2005) additionally associated production of a large amount of non-essential information, with possible conceptualisation difficulties in aphasia. This particularly took the form of overly detailed descriptions. For example, Cairns et al. (2007) report one participant with aphasia (Ron) who described a picture depicting a fairy that is spraying a swimmer with a hose as follows: *"tap, hose, and pixies, elf, woman long hair – no short – no bob and pixie and then swimming woman, and cap, obviously, and [gestures goggles]"* (Marshall, 2009, p.6). The authors argued that this overly detailed description may have resulted from Ron having had difficulties identifying or focusing on the key information in the picture. They propose that this behaviour may be a possible central feature of conceptualisation deficits. Importantly, Ron only showed these symptoms at the sentence level, while no increased amount of detail information was observed in his discourse (Cairns et al, 2006).

In contrast, Hameister and Nickels (2018) also observed production of large amounts of non-essential information in some participants with stroke-induced aphasia. However, none of the participants produced overly detailed descriptions. In contrast, the participants produced many comments (e.g., "that is kind of funny"), semantically empty statements (e.g., "she done that") and statements that were generally appropriate to describe the picture but were mentioned by few participants and hence deemed 'non-essential'.

Few studies have investigated the third symptom of possible conceptualisation deficits, temporal and/or causal sequencing errors, in participants with aphasia. For example, Manning & Franklin (2016) report temporal sequencing errors in the Cinderella story recounts of some individuals with aphasia (e.g., "the prince and the princess were dancing […] *Cinders was going to the ball"; Manning & Franklin, 2016, p.423) which were not observed in any unimpaired controls. Similarly, Carragher et al. (2015) report sequential errors in video recounts of four participants with aphasia. Importantly, these studies mainly focused on investigating the participants' ability to verbally link subsequent information within discourse.

In contrast, Hameister and Nickels (2018) assessed participants' ability to conceptualise causal and/or temporal links between individual events of a complex picture even if expressed nonverbally. When analysing the order in which main ideas were produced, they identified 9 out of 50 individuals with aphasia who produced main ideas in an order that was largely different compared to unimpaired speakers.

The underlying cause of the observed differences in order remain unclear: Hameister and Nickels (2018) suggest that a problem conceptualising the depicted events could be one possible explanation. Likewise, Manning and Franklin (2016) also suggest impairments of more generalised cognitive processes as a possible underlying mechanism for the sequential errors they observed. Conceptualisation, and consequently discourse production itself, relies heavily on cognitive resources like semantic processing, working memory, attention and executive functions (Hill et al., 2018; Levelt, 1989; Mar, 2004; Murray, 2012). Hence, a close relationship between cognitive deficits and macrostructural symptoms seems plausible.

Importantly, all the studies that have specifically investigated the link between language impairments and conceptualisation abilities have only included people diagnosed with stroke-induced aphasia. Nevertheless, similar symptoms might also be expected in people with neurodegenerative language impairments like primary progressive aphasia (PPA).

Macrostructural deficits in PPA

PPA is a neurodegenerative disorder, caused by frontotemporal lobar degeneration associated with abnormal TDP-43 or tau deposition, or an underlying Alzheimer's pathology. It is clinically characterised by a deterioration of a person's speech and language abilities (Gorno-Tempini et al., 2011). In 2011, an international expert group agreed on consensus criteria to discriminate three different subtypes of PPA (Gorno-Tempini et al., 2011): non-fluent variant (nfvPPA); semantic variant (svPPA) and logopenic variant (lvPPA). Each subtype is characterised by distinct behavioural symptoms as well as a different underlying pathology (Gorno-Tempini et al., 2011).

As in stroke-induced aphasia, discourse analysis is commonly used to investigate the general language abilities of people with PPA and distinguish the different subtypes (for review see Boschi et al., 2017). Research groups have elicited discourse samples using, for example, the Cookie Theft picture description (e.g., Graham, Patterson, & Hodges, 2004) or wordless picture book story telling (e.g., Frog, where are you; Ash et al., 2006) and analysed word retrieval and syntactic structures as well as macrostructural features like informativeness and coherence.

Similar to the patterns found in participants with stroke-induced aphasia, Ash and colleagues (2006) reported that all PPA variants showed reduced informativeness represented by missing or ambiguous content units in their discourse (Ash et al., 2006; Ash & Grossman, 2015; Graham et al., 2004).

To our knowledge, Graham et al. (2004) is the only study, to date, to investigate non-essential information in participants with PPA (only nfvPPA). Similar to Hameister and Nickels (2018) in stroke-induced aphasia, Graham et al. (2004) identified a variety of non-main concept types in the picture descriptions of individuals with nfvPPA: general comments (e.g., "It's a strange situation"; Graham et al., 2004, p.145), repeated information (e.g., "the grown-up woman"; Graham et al., 2004, p.145) and ambiguous information (e.g., "she has them open"; Graham et al., 2004, p.145). These types of non-main concepts might signal difficulties identifying or focusing on main information in the picture description. Ash and Grossman (2015) also reported that individuals with lvPPA produce "a good deal of extraneous talk" (Ash and Grossman, 2015, p. 42). However, they did not further analyse the content of this non-essential information.

Although temporal and/or causal sequencing has not been investigated yet in the discourse of PPA, Ash et al. (2006) did investigate how participants with PPA verbally linked individual events (e.g., using pronominal referents) in the 'Frog, where are you' story (i.e., local connectedness) and if they understood the point of the story (global connectedness).

Ash et al. report reduced local verbal connectedness (e.g., incorrect use of adverbials and pronouns) in some participants with nfvPPA, while their general ability to understand and maintain the topic was reported to be intact (Ash et al., 2006; Ash & Grossman, 2015). Similar findings were reported for some participants with lvPPA (Ash & Grossman, 2015). In contrast, participants with svPPA showed a more severely impaired ability to locally and globally connect the depicted events in the Frog story than participants with nfvPPA and lvPPA.

The macrostructural symptoms reported for individuals with PPA correspond to some extent with the three previously reported symptoms of a possible conceptualisation deficit (e.g., Hameister & Nickels, 2018). Nevertheless, it is important to acknowledge that PPA is a rarely diagnosed language impairment and consequently few participants have been studied so far (Ash and Grossmann, 2015: combined across studies a total of 20 nfvPPA; 14 svPPA; 15 lvPPA; Graham et al., 2004: 14 nfvPPA). Analysis of a larger group of participants with PPA, who are directly compared within one study, is therefore necessary to confirm the presence of the macrostructural deficits that may be associated with underlying conceptualisation difficulties and draw further conclusions to inform the diagnosis of PPA.

Aim

In this study, we aim to identify potential symptoms of conceptualisation deficits in individuals with PPA and compare their prevalence across the three variants.

Based on the literature in stroke aphasia, we hypothesise that participants with PPA who have conceptualisation impairments would display macrostructural symptoms, including 1) a reduced number of main concepts, 2) an increased number of non-main concepts, and/or 3) a main concept order that differs largely from unimpaired controls.

We further hypothesise that conceptualisation difficulties may occur in each PPA variant: A gradual loss of concept knowledge is the predominant symptom in svPPA, therefore participants of this variant might also be prone to conceptualisation difficulties in the speech planning process.

Nevertheless, in stroke-induced aphasia, presumed conceptualisation deficits have been most commonly reported in participants with grammatical impairments (Cairns et al., 2007; Dean & Black, 2005). The authors of these reports have suggested that event-processing deficits may underpin these participants' macrostructural symptoms and their agrammatism. Given the prominence of agrammatism in nfvPPA, a similar association might be expected for some participants with this variant.

Finally, we might also expect conceptualisation difficulties in participants with lvPPA. Apart from word finding difficulties, participants with lvPPA are also reported to show considerable working memory difficulties that might affect their macrostructural organisation of discourse (e.g., Ash & Grossman, 2015).

The results of this study will contribute to a more complete picture into the variety of cognitive impairments in PPA and may provide valuable insights for the assessment of PPA in clinical practice.

General Method

Participants

Participants were recruited between 2008 and 2015 through FRONTIER, a clinical frontotemporal dementia research group in Sydney. All participants were English native speakers or used English as their primary language before the age of 14 and showed no diagnosed visual perception deficits (e.g., neglect) or other uncorrected visual impairments. Unimpaired participants were selected from the database to investigate the picture descriptions of people without any cognitive difficulties and compare this to people with PPA. Participants with PPA also needed to have a confirmed diagnosis of either non-fluent variant PPA (nfvPPA), semantic variant PPA (svPPA) or logopenic variant PPA (lvPPA) based on the current international consensus diagnostic criteria for PPA (Gorno-Tempini et al., 2011). Further, they must have completed the Addenbrooke's Cognitive Examination (ACE; Hsieh, Schubert, Hoon, Mioshi, & Hodges, 2013; Mioshi, Dawson, Mitchell, Arnold, & Hodges, 2006), the

Sydney Language Battery (SydBat; Savage et al., 2013) and a verbal Cookie Theft picture description (Goodglass, Barresi, & Kaplan, 1983).

From the participants who fulfilled these criteria, we randomly selected 20 individuals of each PPA subtype (36 female) and 20 healthy subjects (9 female) from the FRONTIER database. When we refer to individual participants, we use participant identification codes (IDs). All IDs of participants with nfvPPA start with ‘N’ (e.g., N1, N2, …), those of participants with svPPA start with ‘S’ (e.g., S1, S2, …), participants with lvPPA start with ‘L’ (e.g., L1, L2, …) and the IDs of unimpaired control participants start with ‘C’ (e.g., C1, C2, …). The participant groups did not differ in age ($F(3,76) = 0.82$, $p=.49$) or number of years of education ($F(3,76) = 2.08$, $p=.11$; see Table 1).

Table 1: Means (± standard deviations) of demographic data and background test results for each participant group in this study and pairwise comparisons of test values between all experimental groups

	Age	**YoE**	**ACE**			**Digit Span**	**Max. forward digit span**	**SydBat**		**TROG 2 (n=80)**	**SYDBAT - Naming (n=30)**	**mean number words/ description**
			total (max.100)	Attention (max. 18)	Visuo-spatial (max.16)			sem. assoc. (n=30)	Comp. (n=30)			
nfvPPA	66.7 (±8.4)	12.6 (±3.1)	80.8* (±10.2)	16.65 (±1.7)	14.8 (±1.4)	11.8* (±3.1)	5.1* (± 1.02)	25.8* (±4.2)	28.3 (±2.4)	65.2* (±12.0)	21.4* (±4.9)	71.60 (±50.9)
svPPA	63.5 (±5.8)	13.05 (±3.0)	59.6* (±15.5)	15.6* (±1.8)	14.5 (±1.9)	16.0* (±4.9)	6.55 (±1.47)	18.7* (±5.7)	18.7* (±7.3)	67.2* (±15.0)	5.9* (±5.1)	100.15 (±73.8)
lvPPA	66.0 (±7.4)	12.7 (±3.9)	63.0* (±14.42)	13.8* (±2.9)	12.6* (±3.0)	9.6* (±3.6)	4.6* (±1.50)	25.6* (±3.5)	26.7 (±2.5)	51.1* (±21.2)	14.9* (±5.9)	98.60 (±52.0)
controls	66.2 (± 6.3)	14.75 (±2.2)	96.4 (±2.3)	17.8 (±0.6)	15.7 (±0.5)	19.7 (±4.3)	7 (± 1.19)	29.3 (±0.9)	29.3 (±1.0)	78.6 (±0.9)	27.4 (±1.6)	140.60 (±82.8)
Comparison between groups (Paired t-tests, p, two -tailed)												
nfvPPA vs												
svPPA	.94	1.00	<.001^	.13	.68	<.001^	.002^	<.001^	<.001^	.68	<.001^	.53
lvPPA	1.00	1.00	<.001^	<.001^	<.001^	.08	.46	.87	.45	.013^	<.001^	.53
svPPA vs. lvPPA	1.00	1.00	.36	.013^	.007^	<.001^	<.001^	<.001^	<.001^	.006^	<.001^	.94

Note: nfvPPA = non-fluent variant PPA; svPPA = semantic variant PPA; lvPPA = logopenic variant PPA; YoE = Years of education; ACE = Addenbrooke's cognitive examination (Hsieh et al., 2013; Mioshi et al., 2006); total = total ACE score, Attention = ACE subtest attention score; Visuospatial = ACE subtest visuospatial skills score; SYDBAT = Sydney Language Battery (Savage et al., 2013); Comp. = single word comprehension; sem. assoc. = semantic association; TROG = Test for Reception of Grammar-2 (Bishop, 2003); *significant difference to controls, ^ significant difference between groups (Holm corrected p-value)

All participants with PPA underwent comprehensive neuropsychological and neurological testing. If a participant with PPA was assessed more than once, we selected the data from the first appointment. Unimpaired participants were assessed following the same test protocol that was used for individuals with PPA.

The group of participants with svPPA showed the overall most severe language impairments, with naming being particularly impaired (see Table 1). In sentence comprehension the group of lvPPA was the most severely impaired. In contrast, participants with nfvPPA show comparatively mild impairments across all background tests. Interestingly, there was no significant difference across groups in the average number of words the participants produced in their picture descriptions.

General cognitive performance was assessed using the Addenbrooke's Cognitive Examination (ACE; Hsieh et al., 2013; Mioshi et al., 2006). It should be noted, that many of the ACE subtests (e.g., memory, fluency, attention) rely on participants' language ability. Hence, a participant with severe language impairments and intact general cognition might also show an ACE score outside the normal range. Mirroring the pattern of language impairments, the nfvPPA group showed significantly higher scores on the ACE than the lvPPA and svPPA group who did not differ.

Material

We used the 'Cookie Theft' picture (Goodglass et al., 1983), which is part of the FRONTIER routine diagnostic protocol, to elicit the connected speech sample for our analysis. Different experienced clinicians administered the task and the task instructions varied between the individual clinicians (e.g., "Please tell me what is happening in the picture." or "Please describe the picture in as much detail as possible."). Since our analysis also investigated the amount of detail in the description, the exact wording of the instruction was noted whenever a recording was available (47 out of 80 samples).

All ‘Cookie Theft’ descriptions were orthographically transcribed. Transcriptions were stopped when the participants ended their description or as soon as the examiner provided a prompt (e.g., “Is there something else?”; “What is the boy doing?”). Every utterance that followed a prompt was disregarded. Hence, only spontaneously produced ideas were included in our connected speech analysis. Unfortunately, no videotapes of the picture description task were available. Thus, non-verbal strategies like pointing or gesturing could not be included in our analysis (cf., Hameister & Nickels, 2018).

Procedure

We investigate macrostructural difficulties using concept analysis (Linnik et al., 2016) to evaluate the overall informativeness of discourse (Nicholas & Brookshire, 1995). The main goal of most concept analysis approaches is to identify the most essential concepts in the participants’ discourse: so-called main concepts. Nicholas and Brookshire (1995) identified seven different main concepts in the Cookie Theft Picture (see Table 2).

Table 2: List of main concepts identified by Nicholas and Brookshire (1995)

#	**Main concept**
1	The woman (mother) is doing dishes.
2	The sink (water) is overflowing (running over).
3	The boy is on a stool.
4	The boy (kids) is getting (stealing) cookies (getting into the cookie jar).
5	The stool is tipping. (the boy is falling.)
6	The girl is reaching for a cookie. (the boy hands the girl a cookie.) *or some mention of a plausible action by the girl or location of the girl.
7	The woman (mother) is not noticing (paying attention).

We first (Analysis 1) confirmed these main concepts using our sample of 20 unimpaired individuals and a slightly different concept analysis approach (see Hameister & Nickels, 2018). Analysis 2 and 3 investigated the number and content of main concepts and non-main concepts the participants produced and compared the results between groups. In Analysis 4, we identified the order in which the healthy participants and participants with PPA produced the main concepts and evaluated qualitative differences between groups. Finally, in Analysis 5, we investigated which linguistic or cognitive parameters influenced the results we observed in the participants' production of main concepts and non-main concepts.

Analysis 1: Identifying main concepts in unimpaired speakers

Method

We extracted every utterance that contained at least one verb from the unimpaired participants' picture descriptions and identified 345 different utterances across all 20 participants. Two independent raters grouped statements that appeared to convey a similar meaning in a different wording - referred to here as concepts (e.g., "the kids are raiding the cookie jar" & "the kids steal cookies"). The raters agreed on 80% (277 utterances). A decision about the remaining 68 utterances was made by consensus. This resulted in identification of 33 different concepts in total (see Appendix A). Importantly, some of these concepts were mentioned by only one individual and seemed only marginally relevant to the depicted story (e.g., "The mother has two eyes and a nose").

In order that all main concepts identified by Nicholas and Brookshire (1995) were included, we defined main concepts (those concepts most essential to convey the events depicted in the picture) as all concepts that were mentioned by at least 55% unimpaired participants.

Results & Discussion

Nine concepts reached the criterion to be classified as main concepts (see Table 3; please see Appendix B for a comprehensive list of alternative wordings we accepted for each main concept). Although all seven main concepts previously reported by Nicholas and Brookshire (1995) were mentioned by more than 50% of unimpaired controls in our sample, it is interesting to note that the main concept "The boy is on the stool" was produced by 70% of controls in Nicholas and Brookshire's (1995) sample, while only 55% of our sample mentioned this idea. Hence, using the relatively low 55% threshold, to ensure that this concept was included, we identified two further main concepts “There is a garden outside *or some mention of the garden” and “The curtains are drawn back *any description of the kitchen”.

The first four main concepts listed in Table 3 were mentioned by 100% of unimpaired controls in our sample. For the remainder of this paper we will refer to these as ‘central main concepts’. On average, unimpaired participants produced 7.05 (SD: 1.61) main concepts in their picture descriptions.

Table 3: List of main concepts identified and percentage of participants of each group who produced these main concepts in their picture descriptions.

#	Main concepts	Unimpaired	nfvPPA	svPPA	lvPPA
1	The woman (mother) is doing dishes.	100%	90%	70%*	85%
2	The sink (water) is overflowing (running over).	100%	100%	75%*	85%
3	The boy (kids) is getting (stealing) cookies (getting into the cookie jar).	100%	80%	85%	80%
4	The stool is tipping. (The boy is falling.)	100%	90%	70%	95%
5	The girl is reaching for a cookie. (the boy hands the girl a cookie.) *or some mention of a plausible action by the girl or location of the girl.	75%	55%	50%	65%
6	The woman (mother) is not noticing (paying attention).	70%	50%	35%*	45%
7	*Any mention/ description of the garden*	60%	35%	20%*	15%**
8	The boy is on the stool	55%	25%	50%	40%
9	*Any description of the kitchen*	60%	65%	10%**	50%

Note: In italic: main concepts that were not included in the main concept analysis of Nicholas and Brookshire (1995). The asterisks represent a significant difference between the participants with PPA and the unimpaired participants (Fisher exact-test: *p<.05; **p<.01).

Analysis 2: Main concepts in individuals with PPA

The literature shows that conceptualisation deficits can be associated with difficulties focusing on or identifying main information in a target picture (Cairns et al., 2007; Dipper et al., 2005).

Consequently, we predicted that participants with PPA who presented with conceptualisation impairments would produce significantly fewer main concepts in their picture description than unimpaired participants.

Method

As for the unimpaired individuals, we identified concepts by first listing every utterance the participants with PPA produced in their picture descriptions. Due to the participants' expressive language impairments, an utterance was defined as a phrase that seemed to convey one content unit, even if the participant did not produce a verb (e.g., "[…] and then the boy... for the ... for the cookies"). Semantic or phonological errors in the utterances were ignored when the independent raters agreed about the meaning (e.g., "Dad is doing the dishes").

One rater identified utterances that conveyed the same meaning as one of our previously identified main concepts. A second rater also identified main concepts in 20% of the participant's picture descriptions. There was 100% agreement in the raters' identification of utterances and 95% agreement in their identification of main concepts. The raters only disagreed on two main concepts, one in each of two different participants with svPPA, where a decision was made by consensus. All utterances that could not be assigned to one of the main concepts were listed separately and later included in our non-main concept analysis.

Results

We analysed differences in the number of main concepts between groups using an ANOVA and pairwise t-test comparisons (see Table 4). Our results showed a significant difference in the number of main concepts between groups ($F(3,76)=6.142$, $p<.001$). Pairwise comparisons showed that the group of individuals with svPPA produced significantly fewer main concepts than unimpaired individuals (see Table 4). No significant differences were found between PPA variants.

Table 4: Mean number and standard deviation (SD) of main concepts produced by each group and between group comparisons (pairwise t-test)

	Mean number of main concepts (± SD)	**Comparisons t-scores**		
		nfvPPA	*svPPA*	*lvPPA*
controls	7.05 (±1.6)	-2.11	-4.32*	-2.70
nfvPPA	5.90 (±1.8)	--	2.12	0.52
svPPA	4.65 (±1.9)		--	-1.63
lvPPA	5.60 (±1.7)			--

Note: * p<.05 (Holm corrected)

Nevertheless, we identified 16 individuals with PPA across all variants who produced significantly fewer main concepts than unimpaired speakers (≤ 4 main concepts, Singlims (Crawford, Garthwaite, Azzalini, Howell, & Laws, 2006) $t < -1.85$, $p<.05$). Half of these individuals (n=8) were participants with svPPA, three were diagnosed with nfvPPA and five with lvPPA.

We further identified 24 participants across all variants who also omitted at least one central main concept that was mentioned by 100% of unimpaired participants, 15 of whom showed a significantly reduced number of main concepts.

The svPPA group were particularly likely to omit the central main concepts: "the mother is washing the dishes" (Fisher exact: p= .01) and "the sink is overflowing" (Fisher exact: p= .02; see Table 3). In contrast, the lvPPA group only showed a difference for the descriptive elements about the "garden" (Fisher exact: p=.004) and were just as likely to produce the central main concepts as the unimpaired speakers (see Table 3). The group with nfvPPA showed no significant difference to unimpaired speakers in main concept production.

Discussion

As predicted, some participants with PPA (40%) across all variants produced significantly fewer main concepts (< 4 main concepts) than controls and/or omitted at least one central main concept. This supports Ash and Grossman (2015) who observed such a similar lack of essential information for participants from all variants. Considering the participants' expressive language impairments, the first assumption would be that linguistic deficits, like word retrieval difficulties or increased speaking effort, might be responsible for the lack of essential information (Ash et al., 2006; Ash and Grossman, 2015). However, in people with stroke-induced aphasia, reduced informativeness has also found to be associated with conceptualisation difficulties in the form of difficulties identifying the main events (e.g., Marshall et al., 1993; Cairns et al., 2007). For participants for whom this is true, we might also expect more production of less-central information (non-main concepts). To further investigate the mechanisms underlying the reduced informativeness, we next analysed the number of non-main concepts in the participants' picture descriptions.

Analysis 3: Non-main concept statements

The majority of our participants with and without PPA produced at least one statement that could not be classified as a main concept. Both Cairns et al. (2007) and Hameister and Nickels (2018) suggest that a large number of non-main concept statements may indicate possible difficulties focusing on the most important information in the picture. In particular, it was hypothesised that conceptualisation impairments may be associated with increased descriptions of details. Therefore, we evaluated the number, proportion and types of non-main concept statements that unimpaired controls and participants with PPA produced and compared the groups.

Method

We listed all utterances in the unimpaired participants' picture descriptions that did not relate to any of the nine main concepts. We identified four different categories of non-main concepts that represented the characteristics of these utterances (cf., Hameister & Nickels, 2018):

1) *Plausible ideas* encompassed statements that seemed appropriate to describe the depicted scene, but were mentioned by less than 55% of the unimpaired participants. These

statements most commonly were related to the mother standing in a pool of water, the boy passing a cookie to his sister and the inference that the sink was probably blocked.

2) *Descriptions of details* mostly contained statements that described the mother (e.g., “the mother is wearing an apron”), the children (e.g., “the girl has neat socks”) or the property (e.g., “outside you can see another wing of the building.”).

3) *Irrelevant comments about depicted entities/events*, summarised remarks that broadly concerned depicted entities or events but did not relate directly to the narrative of the picture (e.g., “there is going to be a screaming match”; “I wonder why it’s leaking”).

4) *General comments* summarised general remarks the participants made about the scene or their own performance (e.g., “it’s a crowded picture”; “I think it starts here”; “that’s all”).

For individuals with PPA, it was necessary to add a fifth category – *ambiguous information* – in order to classify all non-main concept statements (cf., Hameister & Nickels, 2018). This category contained utterances that seemed to convey meaning but were uninterpretable due to missing referents or semantic errors (e.g., “and the water through it’s that one”).

Two independent raters assigned all 315 non-main concept statements to these subgroups. They agreed in their assignment of 263 statements (83%). Disagreements were discussed and solved by consensus.

Results

We observed large inter-individual differences in the number of non-main concepts across the participant groups (see Table 5, Figure 1A). Hence, to evaluate if participants with PPA showed an unusual rate of non-main concept production, we compared the proportion of non-main concepts relative to main concepts in the participants’ picture description.

Table 5: Mean number, proportion and standard deviations (SD) of non-main concepts produced by each group and between group comparisons (pairwise t-test)

	Mean number of non-main concepts (± SD)	**Mean proportion of non-main concepts (± SD)**	**Comparison of proportions: t-scores**		
			nfvPPA	*svPPA*	*lvPPA*
controls	4.45 (±4.6)	0.31 (± 0.19)	-1.72	1.54	1.63
nfvPPA	1.85 (±2.2)	0.24 (± 0.20)	--	-3.05*	-3.33*
svPPA	4.85 (±6.0)	0.41 (± 0.24)		--	0.09
lvPPA	4.60 (±3.6)	0.41 (± 0.19)			--

Note: * p<.05 (Holm-corrected)

Overall, we found a significant difference in the proportion of non-main concepts between groups (F(3,76)=4.607, p=005; see Figure 1B). At a group level, the svPPA and lvPPA groups produced significantly larger proportions of non-main concepts than the nfvPPA group. No significant differences were found for any other comparison, including between the PPA and control groups.

At an individual level, we found nine individuals with PPA (5 svPPA and 4 lvPPA) who produced a significantly higher proportion of non-main concepts than the average of unimpaired controls (Singlims, Crawford et al., 2006: proportion of non-main concepts per picture description ≥ 67%, t=1.76, p=.048).

It is of note that four of the participants who produced an unusually large proportion of non-main concepts received instructions that encouraged them to provide a detailed picture description (for L5: "I want you to look at this picture and tell me everything that you see in it."; for S14: "[…] as best as you can. Try to tell me all about it"; L14: "Tell me everything that you see on it."; S10: "Give me as much of a description as you can").

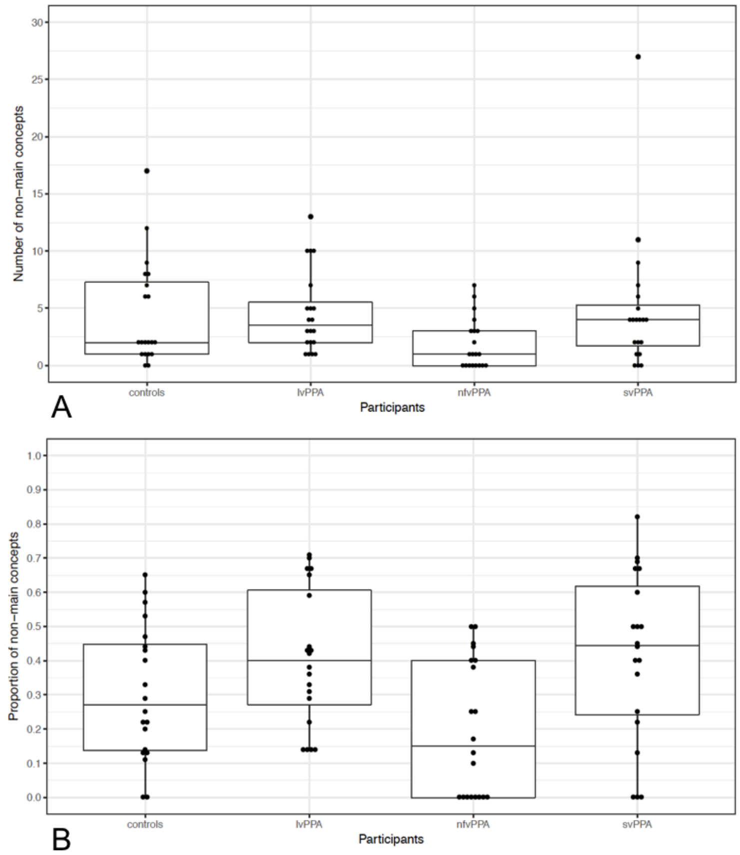

Figure 1: Panel A: Number of non-main concepts per picture description across participants; **Panel B**: proportion of non-main concepts per picture description across participants

Note: The band inside the box represents the median, the box encloses the middle two quartiles of the data.

We next analysed the subtypes of non-main concepts that were produced across all participants of this study. Comparing across the variants of PPA, we found a significant difference in the pattern of subtypes of non-main concepts (Total number of each of the subtypes of non-main concepts summed across participants within each group: $X^2(8) = 23.3$, p=.003; see Figure 2).

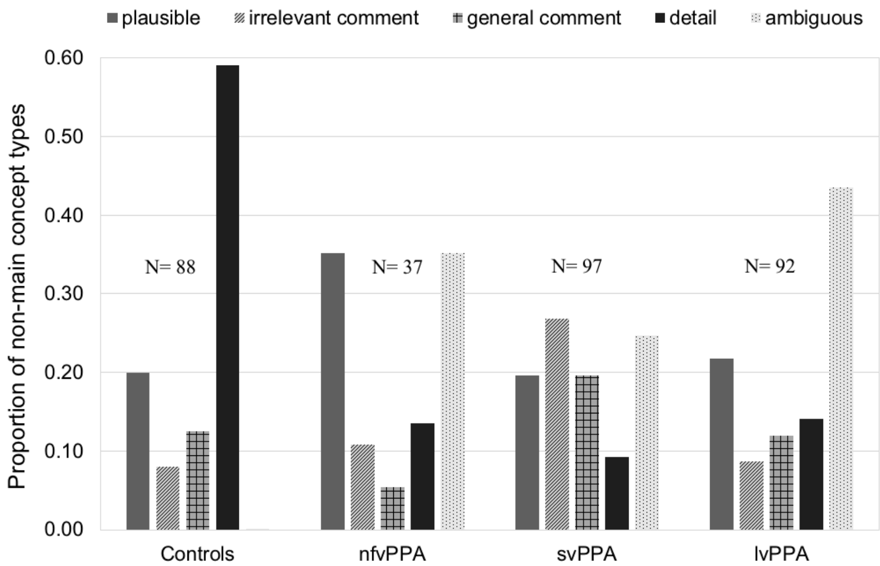

Figure 2: Proportion of non-main concept types across participant groups
Note: Total number of non-main concepts was nfvPPA n=37; svPPA n=97; lvPPA n=92; unimpaired n=88

When we compared the patterns of non-main concept subtypes across groups, the nfvPPA group did not differ significantly from either of the other PPA groups or unimpaired controls. In contrast, the svPPA group was significantly more likely to produce *general comments* than the nfvPPA group (t = 3.47, p=.002). Moreover, they produced a significantly higher proportion of *ambiguous statements* than controls. The largest proportion of ambiguous statements, however, was observed in the lvPPA group, who produced significantly higher proportions of *ambiguous statements* than controls (t = 3.56, p<.001) and the svPPA group (t= 2.69, p=.011).

Surprisingly, the unimpaired participants produced the largest proportion of *descriptions of details* (see Figure 2). Participant C6 produced 15 *descriptions of details*, which was by far the highest number of any participant in our sample. Large numbers were also produced by C5 (6), C16 (8) and C19 (6). In contrast, none of the participants with PPA produced more than four *descriptions of details* (see Figure 3).

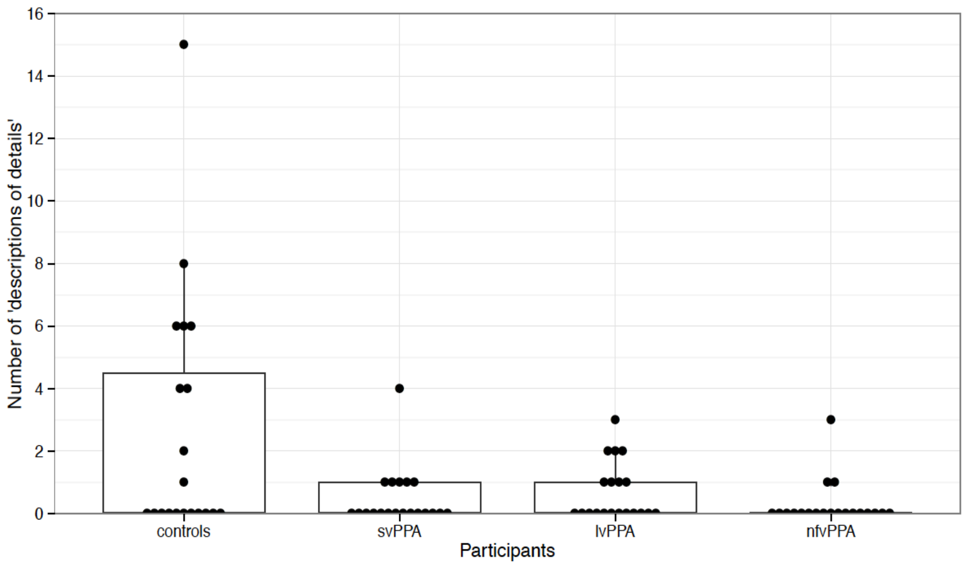

Figure 3: Number of *descriptions of details* across participant groups

In addition to the group analysis, we observed one participant with svPPA (S14) who produced an unusual large number of irrelevant comments about the depicted entities/events. No other participant in our sample produced anywhere near as many (see Figure 4).

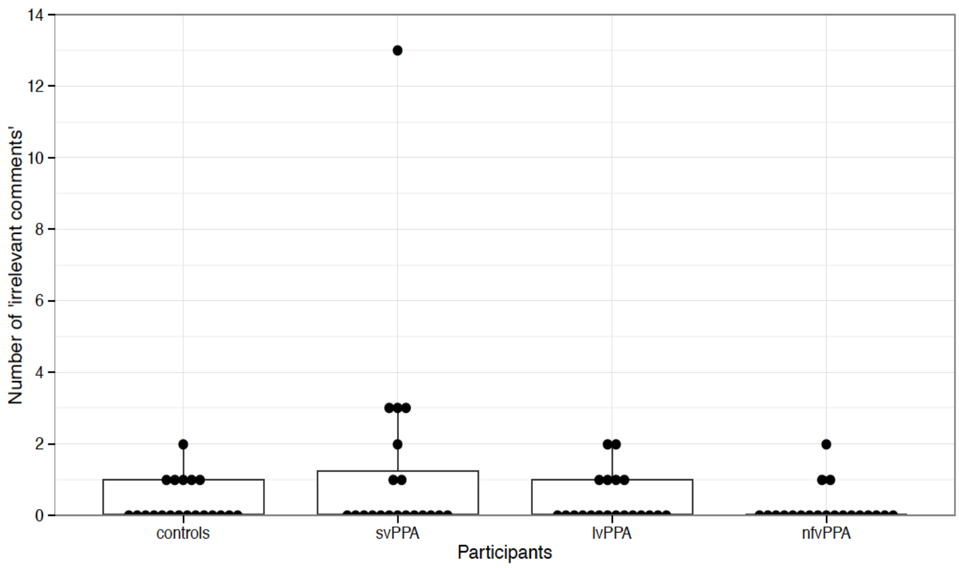

Figure 4: Number of *irrelevant comments about depicted entities/events* across participants

As can be seen in the sample in Table 6, S14 seems easily distracted and it is hard to follow her picture description. In particular, she adds comments after each descriptive statement expressing her confusion about the scene.

Table 6: Example of participant S14's picture description in which *irrelevant comments about depicted entities/events* are underlined

S14 - excerpt of picture description
"Look there is an open window there. I wonder why she's got the open window when she's doing the washing. I wonder though it's hot. She's looking a bit a bit worried - look at her face. I wonder why she's that face looks like she is not happy about something. Look she's wiping the dish. I wonder why she's doing that"

Note: underlined = statements identified as *irrelevant comments*

Discussion

We hypothesised that conceptualisation deficits would result in production of an increased proportion of non-main concepts due to difficulties focusing on the main information depicted in the scene. However, our results showed that participants with PPA did *not* produce significantly larger proportions of non-main concepts than controls. Similar findings were reported by Graham et al. (2004) for participants with nfvPPA and Hameister and Nickels (2018) for participants with stroke-aphasia.

Nevertheless, at an individual level, there were nine participants with PPA who produced a significantly larger proportion of non-main concepts than controls. Importantly, only four of these participants were given instructions to describe "as much as possible", which could have been a potential influence. The five other participants with PPA received the standard instruction of "please tell me what is happening in the picture". Consequently, task instructions alone cannot account for the observed large proportions of non-main concepts for these participants.

Concerning the types of non-main concepts, we expected a particularly large amount of *descriptions of details* in individuals with PPA with conceptualisation impairments. This hypothesis was mainly based on single case reports of participants with stroke-aphasia (e.g., Cairns et al., 2007; Marshall et al., 1993). We did not find this in our study with stroke-aphasia (Hameister & Nickels, 2018) and it was also not apparent here.

Rather than excessive detail, we observed a large proportion of *ambiguous statements*, particularly in the svPPA and lvPPA groups. It seems plausible that these might be underpinned by either linguistic deficits (e.g., word retrieval impairments) or profound conceptual-semantic deficits (e.g., loss of object knowledge) (Ash et al., 2006). An analysis of the participants' overall pattern of impairment is required to make more specific hypotheses and we will return to this in the General Discussion.

Interestingly, we observed one participant who produced a particularly large number of *irrelevant comments about depicted entities/events*. Since the number of main concepts S14 produced lay within the normal range, we suggest that she was able to identify the essential elements in the 'Cookie Theft' picture but had difficulties staying focussed on only these elements. It is possible that such an underlying impairment, would also lead to difficulties in appropriately sequencing information. This was examined in the next analysis.

Analysis 4: Order of main concept statements

Our final hypothesis related to the participants' ability to conceptually link the individual information units (main concepts). We hypothesised that participants with difficulties in conceptually linking the main concepts in their picture description would show a significantly different main concept order to unimpaired controls.

Method and Results

We first evaluated the agreement in the exact order of main concept production across unimpaired participants. This was required to identify a main concept order that was produced by most controls.

On initial inspection of the data it became obvious that half of the participants started with a main concept about the MOTHER while the other half started their description with a statement about the CHILDREN. Consequently, no common main concept order could be identified across all participants. However, further qualitative analysis showed that all unimpaired speakers first completely described the events in one part of the picture (MOTHER: doing the dishes, sink is overflowing; or CHILDREN: stealing cookies, falling over), before moving on to describe the other part.

A similar pattern was found in the picture descriptions of individuals with PPA. Once again, about half of the participants started either with a statement about the MOTHER (27/60 participants with PPA; nfvPPA: 11/20; svPPA: 7/20; lvPPA: 8/20) while the other half began their description with a statement about the CHILDREN (33/60 participants with PPA; nfvPPA: 9; svPPA: 13; lvPPA: 12). Overall, 57 individuals with PPA (95%) completely described one part of the picture (either about MOTHER or CHILDREN) before moving on in their description. An example transcript of one participant with lvPPA (L13) who clearly showed this pattern is displayed in Table 7. The table shows the individual statements in the order in which they were produced, with each statement assigned to a description of events associated with either the MOTHER or the CHILDREN.

Table 7: Transcript of L13's picture description in the exact order it was produced illustrating the description of events concerning the CHILDREN followed by events concerning the MOTHER.

	Events concerning the CHILDREN	**Events concerning the MOTHER**
MC	okay the little girl is standing against the the um stool	
MC	with the little boy on it	
MC	and it he is going to try to get the cookie jar	
nonMC	because the the clicking the door was as well as a a jar and	
nonMC	and the boy is stall was looking like him	
MC	was going to come down	
MC		and mum is not looking
MC		she is wiping the the plate
nonMC		because there is there is a plate and two cups
nonMC		and there is the water
MC		a and it is coming up out of the basin
nonMC		and around her her shoes and

Note: MC = main concept; nonMC = non-main concept

Nevertheless, three individuals with PPA (L2, L6, and N11), unlike unimpaired participants and the majority of people with PPA, jumped between statements about the

MOTHER and the CHILDREN within their picture description. The transcript of one participant with lvPPA (L6) is shown in Table 8 to illustrate this behaviour. Once again, the individual statements were classified as either concerning the MOTHER or the CHILDREN, while neutral statements are shown in a merged cell.

Table 8: Transcript of L6's picture description in the exact order it was produced illustrating the switching between description of events concerning the CHILDREN and events concerning the MOTHER.

	Events concerning the CHILDREN	**Events concerning the MOTHER**
MC	the kids getting off the cooking he's going off the … he's got the cookie jar there	
MC		and it's [water] pouring off here onto
nonMC	the stool there {…the floor}	
MC (repetition)		then she's [mother] here
MC (rep.)		and it's overflowing with water
nonMC		and she is trying - you know doing it with her teesh- tea towel
MC (rep.)		but the water is out there
nonMC		they're floating up
nonMC	*there is just the two things*	
MC	he's gonna fall down	
MC (rep.)		and she's [mother] gonna get water and all of that sort of thing that's coming
MC	I don't know whether she [girl] is laughing at him	
nonMC		she [the mother] is just standing there
MC		as if she hasn't even seen the water

Note: MC = main concepts, nonMC = non-main concepts; rep. = repetition; text within [ ] is the intended referents for personal pronouns used in the description; { } contains intended meaning of words that were distorted by a semantic or phonological errors or omitted.

Like L13, L6 started her picture description with a statement about the CHILDREN. However, in contrast to L13, L6 switched between the two main topics after almost every concept. Hardly any concepts were semantically or grammatically linked to each other. Hence, L6's picture description appears rather like a listing of individual events than a coherent description. We found a similar pattern in the picture description of the other two participants with PPA (see Appendix C).

Discussion

Levelt (1989) described appropriate sequencing of information as an important part of the macrostructural process and essential to form coherent discourse. Surprisingly, there was no single main concept order in the picture descriptions of the unimpaired controls. This is in contrast to our experience with a different picture description task (Hameister & Nickels, 2018). In the 'Cookie Theft' picture, equal numbers of unimpaired participants and participants with PPA chose to begin their descriptions with events concerning the MOTHER or with events concerning the CHILDREN. Critically, however, all unimpaired participants finished their description of one set of events before starting the next. In contrast, three participants with PPA alternated between statements about the MOTHER and statements about the CHILDREN and did not communicate any clear causal or temporal relationship between them.

This jumping between the two foci of the 'Cookie Theft' has previously been reported in picture descriptions of participants with Alzheimer's type dementia (Schultze-Jena, 2001). Schultze-Jena proposed that the participants had difficulties maintaining their focus of attention in one area and therefore jumped to a different object after each statement. We further discuss possible underlying mechanisms for these order differences in the General Discussion.

Analysis 5: Influencing factors

Cognitive deficits, for example in attention, semantic processing and working memory, have previously been associated with discourse impairments like reduced informativeness and coherence (e.g., Ash & Grossman, 2015; Graham et al., 2004; Hill et al., 2018). Hence, to better inform our understanding of underlying mechanisms, in this analysis we investigated whether performance on any of the available background assessments influenced the number of main concepts and non-main concepts produced.

If conceptualisation deficits underpin the patterns we observed, then we might predict an association between a reduced number of main concepts and/or a large proportion of non-main concepts and impaired performance on cognitive tasks such as ACE, SydBat semantic association and/or digit span score. In contrast, a correlation between impaired linguistic performance (e.g., Naming, Comprehension, TROG) and a reduced number of main concepts and/or a large proportion of non-main concepts would support the idea of primarily linguistic deficits (e.g., impaired lemma access) as the most likely underlying mechanism.

Method

For each experimental group (controls, nfvPPA, svPPA and lvPPA), we first calculated correlations between the number of main concepts and the proportion of non-main concepts, and all additional performance measures: ACE; ACE-attention; ACE-visuospatial abilities; SydBat semantic association; digit span; SydBat comprehension; TROG; SydBat naming and number of words in the picture description. We Bonferroni corrected for multiple comparisons and hence set the significance level as $p<.006$. We additionally ran Bayesian correlations to gain further evidence for the strength of the evidence for associations (or lack of associations). Only correlations that were both significant (Bonferroni corrected) and had a Bayes factor of >10 (strong evidence for the hypothesis of an association) were considered further.

We then performed linear regressions to identify which of the significantly correlated variables were unique predictors of the number of main concepts in people with PPA. In order to prevent multicollinearity, we only included variables with sufficiently low intercorrelations (see Appendix D; $r<.80$; Hutcheson & Sofroniou, 1999) in these regressions.

Results - number of main concepts

The correlations between the participants' number of main concepts, proportion of non-main concepts and their background test results are displayed in Table 9 (see Appendix D, for full correlation matrices).

Table 9: Pearson's correlations between the participants' number of main concepts and non-main concepts and the results of all administered background tests

	Controls		**nfvPPA**		**svPPA**		**lvPPA**	
r =	# MC	% nonMC	# MC	% nonMC	# MC	% nonMC	# MC	% nonMC
# MC		.48		-.14		.17		-.38
ACE total	.23	.26	.57	-.46	.79*+	.23	.27	-.21
ACE attention	.14	-.17	.45	-.53	.49	.04	.12	-.28
ACE visuospatial	-.05	.002	.56	-.27	.70*+	.27	-.07	.04
SydBat Semantic	.12	.17	.63*+	-.15	.41	.41	.14	.02
Digit span	-.03	-.06	.12	-.62*+	.44	.38	.12	-.36
SydBat Comprehension	.11	.01	.56	-.29	.58	.28	.20	-.37
TROG	.31	.25	.35	.19	.68*+	.48	.09	.15
SydBat Naming	.18	.12	.59	-.46	.66*+	.26	.59	-.50
# words	.82*+	.81*+	.76*+	.38	.53	-.46	.40	.42

Note: MC =main concept, nonMC = non-main concept; # = Number; % = proportion; *p<.006 (Bonferroni corrected p-value); +Bayes-Factor > 10 (strong evidence in favour of H1)

Controls

Only the number of words in the description was significantly correlated with the number of main concepts in the picture descriptions of unimpaired controls. The remaining variables only showed small (nonsignificant) correlations. This can most likely be explained by ceiling effects, caused by the high test scores of controls.

nfvPPA

For participants with nfvPPA, the number of words and SydBat semantic association were both highly correlated with the number of main concepts and the Bayesian analysis provided strong evidence of an association. Hence, we ran a linear regression models (see Table 10) to examine the unique variance of those two variables.

The model explained 62% of the observed variance, however, only the number of words in the participants picture description was a significant predictor of the number of main concepts.

Table 10: Results of linear regressions to identify best predictors for the number of main concepts in participants with nfvPPA and svPPA

nfvPPA					
	B	**SE B**	***ß***	**t**	**p**
Model: semantic association + #words					
SydBat semantic association	-.144	.072	.33	2.01	.061
#words	.021	.006	.59	3.59	.002**
					R^2 = .62, *p*<.001
svPPA					
	B	**SE B**	***ß***	**t**	**p**
Model 1: ACE + TROG					
ACE	.069	.027	.56	2.58	.021*
TROG	.037	.027	.29	1.35	.197
					R^2 = .57, *p*<.001
Model 2: ACE-Visuospatial + Naming + TROG					
ACE -Visuospatial	.37	.26	.31	1.43	.17
SydBat Naming	.08	.08	.20	0.91	.38
TROG	.05	.03	.41	1.97	.07
					R^2 = .52, *p*=.004

svPPA

For participants with svPPA, scores on the ACE, the ACE subtest for visuospatial abilities, the SydBat naming subtest and the TROG were all significantly correlated with the number of main concepts. Bayesian analysis also provided strong evidence of an association for these measures.

As the ACE subtest scores are part of the total ACE score, these variables were not included together in one regression model. Additionally, SydBat Naming and the total ACE score were highly intercorrelated (r=.87). Hence, we ran two different logistic regression models for the svPPA group (see Table 10). The model including the total ACE score explained most of the observed variance (57%) and the total ACE score was the only significant predictor of number of main concepts in all models. None of the other significantly correlated variables uniquely predicted performance.

lvPPA

For the group of participants with lvPPA no variable was significantly correlated with the number of main concepts. The highest correlation was found for SydBat Naming (r=.59, see Table 8). However, the p-value of p=.007 was marginally over Bonferroni corrected p-value of p=.006. Consequently, we ran no linear regression.

Results - proportion of non-main concepts

Similar to the analysis of number of main concepts, the number of words in the description was found to be the only variable that was significantly correlated with the proportion of non-main concepts for controls (see Table 9).

In the nfvPPA group we observed significant negative correlations between the proportion of non-main concepts the participants produced and their digit span: a reduced digit span was associated with a large proportion of non-main concepts (see Table 9). No other correlation reached significance.

Furthermore, no significant correlations were found between the proportion of non-main concepts and any of the tested variables for the svPPA and lvPPA groups.

Discussion

The overall number of words in the participants' picture description was the strongest predictor for the number of main concepts in controls and the group of nfvPPA. This seems unsurprising, since it suggests that people who generally say more are more likely to mention essential information. However, a robust association with number of words was not apparent for the number of main concepts produced by svPPA and lvPPA groups. This reflects the fact that even participants who produced relatively few words overall, produced a number of main concepts within the normal range (e.g., L9 (lvPPA): 6 main concepts with only 50 words vs. S12 (svPPA): 6 main concepts with 143 words).

For controls, the proportion of non-main concepts was also strongly associated with the number of words in their descriptions. This reflects the pattern described in Analysis 3 where controls were seen to produce large amounts of additional non-essential information. This implies that controls who produce more words describe the key elements of the picture, and additional appropriate, but non-essential, information. In contrast, there is no such association for any of the PPA variants. This might suggest that, even when their number of words was restricted, some participants with PPA may not have been able to prioritise production of main concepts.

In line with our hypothesis, there was some suggestion for the participants with svPPA and nfvPPA that cognitive skills as measured by the ACE or the SydBat semantic association score may have contributed to the production of main concepts.

The total ACE score was found to be a significant predictor of the number of main concepts for the svPPA group but not for the nfvPPA and lvPPA groups. The svPPA group showed the lowest ACE score and produced the fewest main concepts. Hence, the association between these measures might be particularly salient for this participant group.

However, it is important to note that many of the ACE subtests require language skills. Consequently, the analysis of the participants' cognitive skills might be confounded by their language impairments. For example, the attention subsection involves questions like "What is the date/month/year?" which draws on language and memory skills as well as on the participants' attention.

Finally, we found digit span to be a significant predictor of the proportion of non-main concepts for the nfvPPA group. Interestingly, these participants also had the smallest average number of non-main concepts of all PPA groups. Hence, we suggest it is possible that some of the participants with nfvPPA who produced non-main concepts might have done so because of underlying short-term memory difficulties. We discuss this in more detail in the General Discussion.

General Discussion

Analysing the macrostructural organisation of discourse provides valuable insights into the conceptual stages of the speech planning process (Armstrong, 2000). Hence, in this research, we aimed to identify possible core symptoms of conceptualisation difficulties from analysis of the macrostructural organisation (number and order of main concepts, proportion of non-main concepts) of the 'Cookie Theft' picture descriptions of speakers with PPA.

Thirty-one of the participants with PPA (52%) in our sample produced at least one of the three hypothesised symptoms. While none of the participants showed all three symptoms. Table 11 summarises the distinct symptom patterns we observed in these 31 participants.

Table 11: Summary of results ordered by the observed symptom patterns and PPA variant

Participants	**Main concepts**		**Non-main concepts**	**Order of main concepts**
	Significantly smaller number	Central concept omitted	Significantly larger proportion	switching
Reduced amount of essential information				
N4	X	X		
N13	X	X		
N19	X	X		

S7	X	X		
S11	X	X		
S15	X	X		
S16	X	X		
S19	X	X		
L3	X	X		
L19	X	X		
N1		X		
N8		X		
N15		X		
S1		X		
S4		X		
L15		X		
L11		X		
Increased amount of non-essential information				
Large proportion of non-essential information + reduced amount of essential information				
S3	X	X	X	
S10	X	X	X	
S17	X	X	X	
L1	X	X	X	
L8	X	X	X	
S5		X	X	
S14		X	X	
Large proportion of non-essential information only				
L14			X	
L5			X	
Order switching				
Order switching + large proportion of non-essential information				
L6			X	X
Order switching + reduced amount of non-essential information				
L2	X			X
Order switching only				
N11				X

Note: Participant IDs starting with N refer to individuals diagnosed with nfvPPA, L - lvPPA and S - svPPA.

We will now discuss possible mechanisms underlying each pattern in more detail.

Reduced amount of essential information

The most common macrostructural symptom was a reduction in the production of essential information, represented by omission of central elements (main concepts mentioned by 100% of controls), with or without an overall reduction in number of main concepts. Twenty-four participants (40%) showed this symptom. This replicates the findings of omission of essential information in stroke-induced aphasia (e.g., Cairns et al., 2007; Hameister & Nickels, 2018; Nicholas & Brookshire, 1995).

A reduced amount of essential information has also been reported for individuals with PPA and several possible underlying mechanisms were proposed (Ash et al., 2006; Ash & Grossman, 2015).

One of the most commonly suggested explanations is a direct link between the participants' speech and language impairments and the reduction in essential information, for example, due to overall reduced speech output (e.g., Andreetta et al., 2012; Ash et al., 2006; Christiansen, 1995).

Ash et al. (2006) proposed that the effort associated with speaking, represented by slow and halting speech typically observed in nfvPPA, was the main contributor for reduced speech output and, consequently, the lack of essential information. The same explanation could hold for the three participants with nfvPPA in our sample who produced a reduced number of main concepts.

However, the majority of individuals with nfvPPA in our sample did not show a reduction in main concepts, and the three participants who did were also the most severely impaired participants in the group. Therefore, we suggest that the overall severity of the participants' expressive language impairment also influenced the amount of information produced.

Word retrieval impairments in particular have previously been associated with a lack of essential information in aphasia (e.g., Andreetta et al., 2012; Christiansen, 1995; Hameister & Nickels, 2018) and PPA (Ash et al., 2006; Graham et al., 2004). The picture descriptions of some participants with PPA suggested that they omitted information they were unable to produce. For example, L15 (lvPPA) produced statements like: "This is a mother who's got something over to …{pause} and she's thinking about it".

While we support the idea of underlying linguistic impairments as a possible cause for the decreased amount of essential information, it is important to note that a failure to retrieve the correct word can be underpinned by different impairments. Ash and Grossman (2015) suggest that semantic deficits including impaired object knowledge might be the source of both the observed word retrieval difficulties and the omission of information in discourse in svPPA. Our results showed that our svPPA group contained the largest proportion of participants with a reduction in essential information. Hence, Ash and Grossman's (2015) explanation might also hold for some participants with svPPA in our study.

However, if indeed, some of the participants omitted main concepts because their conceptual-semantic deficits impaired their ability to understand the scene, we might also expect them to mention additional, less essential information.

Increased amount of non-essential information

In line with the hypothesis of an underlying conceptual-semantic impairments, most of our participants with both reduced informativeness and a high proportion of non-main concepts had been diagnosed with svPPA (5 out 7, see Table 11).

In contrast to the general semantic difficulty proposed by Ash et al., (2006), Marshall et al. (1993) and Cairns et al. (2007) suggested that difficulties identifying and processing events in the depicted scene might cause the participants to produce an unusually large amount of non-essential information, and particularly what we have called, *detail descriptions*. Interestingly, however, our participants with PPA hardly produced any extra detail in their picture descriptions. Instead, the most commonly produced non-main concept types, particularly in svPPA and lvPPA, were *ambiguous statements* (e.g., S3: "They are looking for something … getting something out of … out of the place"), which reduced informativeness (number of main concepts) while increasing the proportion of non-main concepts. While it is possible that some participants could not interpret the individual events and therefore remained rather vague in their description (e.g., Cairns et al., 2007; Dipper et al., 2005), it is also possible that others made ambiguous statements because they could not retrieve the correct words (Ash et al., 2006) or had trouble understanding the scene (e.g., Ash et al., 2006; Hameister & Nickels, 2018).

Interestingly, one participant with svPPA showed a particularly unusual symptom pattern. S14 produced the largest number of non-main concepts (27). While many of them were also *ambiguous statements*, the majority was identified as *irrelevant comments* (e.g., “I wonder why it’s leaking. It shouldn’t be leaking like that”). S14 included such comments after almost every main concept she produced. This behaviour suggests that S14 got easily distracted and seemed to have difficulties maintaining attention on the main events. Similar symptoms have been described in the literature on svPPA (e.g., Amici, Gorno-Tempini, Ogar, Dronkers, & Miller, 2006). Attention is argued to play a key role in discourse (Ash & Grossman, 2015; Hill et al., 2018; Levelt, 1989). We believe that difficulties maintaining and shifting attention required to identify and link important events in a picture and conceptualise a coherent picture description, seem the most likely account for S14’s symptoms. Conceptualisation has high attentional demands (e.g., Murray, 2012; Roelofs & Piai, 2011). While visuospatial attention is necessary to decode the depicted events (e.g., Levelt, 1989), sustained attention plays a crucial role throughout the entire speech production (Roelofs & Piai, 2011). Nevertheless, more detailed assessment of S14’s attention (e.g., measures of sustained attention) would be necessary to provide further evidence for this hypothesis.

Importantly, the case of S14 also illustrates how informative and powerful qualitative analysis of non-main concepts can be in order to obtain the fullest possible interpretation of the participants’ performance.

Two participants with PPA (L14 and L5; lvPPA) showed an unusually large number of non-main concepts as the only macrostructural symptom. Interestingly, most of the non-main concepts L14 produced were identified as plausible ideas that were not mentioned by enough unimpaired participants to qualify as a main concept (e.g., [the sink is overflowing] “because she has a plug in or something like that”).

In contrast, L5 produced mainly ambiguous statements. However, these statements also seemed to relate more to additional plausible ideas or main information (e.g. “she is looking there”; “maybe she is coming down here and this is happening there”). Hence, these statements did not impair the overall coherence in the same way that increased numbers of non-main concepts may in other cases (e.g., Cairns et al., 2007; Hameister & Nickels, 2018; Marshall et al., 1993).

It seems likely that the pattern shown by these participants reflects that they just tried to say as much as possible about the picture in order to describe it particularly fully. This variability in how the participants interpreted the task instructions may be and additional factor that influenced the number of non-main concepts in some participants. The hypothesis is further supported by the fact that some of the unimpaired participants also provided a great deal of extra information.

Order switching

The ‘Cookie Theft’ did not enable us to examine impairments in the precise ordering of main concepts in the way we had with stroke-aphasia (Hameister & Nickels, 2018), as unimpaired controls did not produce a consistent order of main concepts. Nevertheless, controls did show a clear pattern of first describing one theme of the picture (CHILDREN or MOTHER) and then the other. We identified three individuals with PPA (L2, L6, N11) who produced a very different pattern - switching between statements about the two themes. One participant, L6, showed order switching in the context of an increased proportion of non-main concepts, another (L2) in the context of a reduced number of main concepts and the third (N11) showed order switching as the only macrostructural symptom (see Table 11).

Sequencing information marks an important part of the conceptualisation process (Levelt, 1989). Consequently, order differences compared to unimpaired controls were predicted to be a key feature of conceptualisation difficulties and have previously been reported in participants with stroke-aphasia (e.g., Carragher et al., 2015; Hameister & Nickels, 2018;

Manning & Franklin, 2016). Interestingly, an unpublished thesis by Schultze-Jena (2001) also reports the switching between the two parts of the Cookie Theft picture for 8 out of 11 people diagnosed with Alzheimer's type dementia. This was attributed to a disorder of higher cognitive function, such as decreased working memory or problems maintaining the focus of attention to one area of the picture.

Working memory has been argued to play an important role in discourse generation (e.g., Levelt, 1989; Mar, 2004) and has been proposed to be associated with a reduction in local and global coherence (Hill et al., 20018). Speakers need to hold the planned sentences of their description in memory while executing the speech plan. Impairments of working memory can therefore lead to disorganised discourse macrostructure (e.g., Levelt, 1989). Impairments of working memory have been reported for individuals with lvPPA in particular (e.g., Whitwell et al., 2015).

Interestingly, most of the non-main concepts produced by L6 seemed to provide similar content to main concepts that had already been mentioned (e.g., *main concept*: "the water is overflowing" vs. *ambiguous*: "she's gonna get water and all of that sort of thing that's coming"). L6 also showed poor complex sentence comprehension (TROG 23/80) and a reduced digit span (correctly repeated strings forward and backward = 3/30, maximum digit span forward = 3 digits), both of which are consistent with an underlying working memory impairment.

In contrast to L6, L2 did not produce an increased amount of non-essential information but did have a reduced number of main concepts. Nevertheless, his background test results also showed poor sentence-picture matching (TROG: 28/80) and a low digit span score (correctly repeated rows forward and backward = 8/ 30; maximum span forward = 4 digits), signalling impaired working memory.

Hence, we suggest that L6 and L2 may have a problem holding in memory the information necessary long enough for speech planning of the whole discourse. This may lead them to search for new information after every statement, and fail to maintain a complete discourse plan, accounting for the inconsistent main concept order in their descriptions.

In line with Schultze-Jena (2001), this might also signal a worsening of working memory difficulties with the worsening of the Alzheimer's pathology associated with lvPPA (Harciarek, Sitek, & Kertesz, 2014).

Finally, one participant with nfvPPA, N11, also showed a switching between the two themes in the picture but the number of main concepts and non-main concepts lay within the normal range. N11 was only mildly impaired overall with high scores on the ACE (91/100), naming (26/30); comprehension (SydBat: 28/30; TROG: 78/80) and digit span (16). Hence, it seems unlikely that N11's linguistic impairments could account for the unusual main concept order nor the cognitive impairments measured here. Consequently, we can only offer tentative speculations regarding the mechanism underlying N11's order switching.

It is known that discourse relies heavily on executive function abilities (e.g., non-verbal planning, inhibition; e.g., Ash & Grossman, 2015; Levelt, 1989) and this is particularly essential to form coherence (e.g., Mar, 2004; Murray, 2012). Moreover, symptoms associated with executive function disorders are commonly reported for individuals with PPA and nfvPPA in particular (e.g., Heidler-Gary et al., 2007; Macoir, Lavoie, Laforce, Brambati, & Wilson, 2017). Our background test data were not sufficient to confirm whether N11 had such an impairment, but if further testing found such a disorder it could account for N11's constant switch of focus.

Summary and Conclusion

In this study, we have examined the macrostructural organisation of discourse in a large group of people with PPA of all three variants. While many of the individuals showed no evidence of macrostructural impairments, 52% of the participants with PPA demonstrated macrostructural deficits represented by a reduced amount of essential information, increased amount of non-essential information and/or an unusual main concept order. Importantly, none of the participants produced all three symptoms as had been previously reported for the single cases in stroke-aphasia (e.g., Cairns et al., 2007).

We propose that for some people with PPA, particularly those with nfvPPA, a lack of essential information in discourse might be caused by linguistic impairments that reduce the overall speech output (e.g., speaking effort, word retrieval difficulties). However, the combination of a reduction in essential information and increase in non-essential information, most commonly observed in svPPA, cannot be explained by linguistic difficulties alone. Instead, we consider it likely that conceptual-semantic impairments (e.g., Ash et al., 2006; Hameister & Nickels, 2018) or deficits processing depicted events (e.g., Cairns et al., 2007; Dipper et al., 2005; Marshall, 2009) may be alternative causes of difficulties conceptualising the depicted scene. These impairments would lead to an inability to produce a coherent description and may lead to the description being 'padded' with large amount of non-essential information.

Similar to Schultze-Jena (2001), we also propose that a general cognitive impairment of functions like working memory and/or attention may also affect macrostructural organisation, resulting in a violation of the sequential order of the discourse (jumping between statements about the MOTHER and the CHILDREN).

In summary, this study shows that information about conceptualisation difficulties can be gained from the 'Cookie Theft' description. Specifically, analysis of non-main concepts (e.g., irrelevant comments about the scene) and observation of switching between statements about the MOTHER and the CHILDREN seem indicative of potential conceptualisation impairments. Identification of these elements of discourse could easily and time-effectively be included in analysis of the standard 'Cookie Theft' description. This would provide a first insights into a participant's conceptualisation that would guide further diagnosis. This should include a more detailed investigation of participants' non-verbal neuropsychological performance and their event processing to gain further information about the underlying mechanisms of the observed discourse deficits and to inform further therapy planning.

Author contributions:

IH and LN designed the research study; DF, JH, and OP recruited and tested research participants; IH and LN analysed the data; IH and LN wrote the paper

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Appendices

Appendix A: List of all 33 concepts identified in unimpaired controls

#	Concepts	# mentions
1	**The mother is doing the dishes**	**20**
2	**The sink is overflowing**	**20**
3	**The boy/ children are stealing cookies form the cookie jar**	**20**
4	**The boy is standing on a stool**	**11**
5	**The stool/boy is about to fall over**	**20**
6	**The mother is not paying attention**	**14**
7	**^Statement about the girl (e.g., she's waiting for a cookie)**	**15**
8	**^Description of the garden (e.g., they have well-trimmed bushes)**	**12**
9	**^Description of the kitchen (e.g., there are few cupboards)**	**12**
10	The mother is standing in (or being splashed by) the water	4
11	The sink is blocked/ the taps are on [reason for overflowing sink]	11
12	The boy got a biscuit/ is passing a cookie down	8
13	The mother looks out of the window	9
14	^Reason for the boy being on a stool	4
15	^Description of the mother (e.g., she is wearing an apron)	8
16	^Description of the children (e.g., the boy has blond hair)	8
17	^Description of the property (e.g., it's a free-standing house)	7
18	^Description of general scene setting (e.g., it's a domestic scene)	6
19	There's going to be a screaming match (argument)	1
20	The young boy is about to hit his head on the bench top	1
21	The mother will possibly wake up from her daydream	1
22	The sink water fills up	1
23	The water is splashing	1
24	There's gonna be a few accidents to clean up	1
25	The water is leaving a puddle	1
26	It is a secret	1
27	Must be summer I think	1
28	Looks as though she goes from left to right to wash up	1
29	I'm assuming it's the mother and not a maid	1
30	There is a woman at a sink	1
31	You can see the cookies	1
32	There are two children, a boy and a girl, out of her view behind her	1
33	The water is puddling on the floor	1

Note: ^ marks very broad concepts rather than an explicit statement; in bold: main concepts (mentioned by more than 55% of unimpaired controls)

Appendix B: List of statements that were accepted as one of the main concepts

Main concept	**Alternatives**
The woman (mother) is doing dishes.	The mother is drying the dishes | Mom is doing the washing up | Mom is busy doing the dishes | Mom is washing up | The mother is doing dishes | The wife is doing the washing up | The wife is drying a dish there | Mom washes or wipes a plates | [There is a mature lady] doing the washing up | The woman is currently drying a plate with a tea towel | The mother is washing up and drying | The mother is drying a plate | The mother is doing the washing up | The woman is wiping the plate {after being washed} | The mother is drying the dishes | The woman is doing the washing up | The mother is wiping the dishes | The lady is wiping up | The mother is wiping up a plate | The lady [is holding a tea towel] as she wipes the plate | The woman is drying a plate | The lady is drying up | She has dried those three (cups) but maybe they are dirty | The mother is washing up | The mother is wiping the plates | The woman is drying a dish
The sink (water) is overflowing (running over).	The sink is overflowing |The water is overflowing from the sink | The sink is overflowing | The water is pouring onto the floor | The water is running over | The water is flowing over the floor | The sink is overflowing on the floor | [Mom forgets] that the sink is overflowing | The sink is overflowing with water | The water tips out of the sink | The sink overflows onto the floor | The water is overflowing onto the floor | The sink is overflowing onto the floor | The taps are overflowing | The sink is overflowing | The water that's overflowing is flowing onto the floor | The lady [has not seen] the overflowing tub in the kitchen | The water from the sink is overflowing onto the floor | The sink is overflowing with water | The sink is overflowing | The water is running out if the sink | The sink is overflowing | The sink is overflowing | The water is puddling on the floor
The boy (kids) is getting (stealing) cookies (getting into the cookie jar).	The children are stealing form the cookie jar | The kids are trying to get cookies out of the cookie jar | The two children are trying to get the cookies out of the cupboard | The boy is stealing a cookie out of the cookie jar | The boy is trying to get to the cookie jar | The boy is reaching for the cookie jar | The son is going to the cookie jar | The boy is trying to get the cookie form the cookie jar | [The boy is opening a cupboard above] to get a cookie out | The young boy is stealing cookies from a cookie jar | The boy is taking cookies out of a jar | The boy is attempting to take the cookies out of the cookie jar | The boy is taking cookies | The kids are raiding the cookie jar | The two kids a boy and a girl are trying to get cookies out of the cookie jar | The boy is getting his sister some cookies | The boy is taking cookies out of the cookie jar from the cupboard | The boy is taking the biscuits out of (the jar) | The kids are getting the cookies out the jar | The children are raiding a cookie jar | The boy [is climbing] to steal a cookie from the cookie jar | The boy is holding a cookie | The boy's got the biscuit in his hand | The boy has his hand in the cookie jar
The stool is tipping. (The boy is falling.)	The boy's stool is about to topple over | The stool is toppling over | The boy is about to go flat on his back | The stool is about to fall over at any minute | The chair is falling out from under him | The stool is falling over | The boy is just about to fall off the stool | The boy is

	overbalancing | The stool is falling over | The boy is falling off the chair | There is a little boy just about to fall off a stool | The stool is tipping over | The stool is about to teeter over | The stool is falling over | The boy is losing his balance | The stool is losing it's balance | It looks like the boy is about to fall | The boy is gonna fall off the chair | The stool is tipping over | The boy is about to fall off the stool | The boy is about to fall off the stool | The boy is overbalancing | The stool is tripping over | The stool looks like it is about to tip over
The girl is reaching for a cookie. (the boy hands the girl a cookie.) *or some mention of a plausible action by the girl or location of the girl.	The little girl is calling out to him | The little girl is just standing there | The girl is not looking at the stool | The girl thinks this is really funny | The girl maybe wants the biscuit | The little girl got the hand to her mouth | The little girl has got her hand up | The girl is waiting for a cookie | The girl is with him | The girl is asking for a cookie | The girl is waiting for him to fall | The girl is waiting for him to give her a cookie | The girl is standing | The girl is looking at the boy with her arm up | The girl has her arm up | The girl wants a cookie | There is a girl standing on the floor | The girl is facing a boy | The girl has her arm raised | The girl has her fingers to her lips | The girl is making the boy keep quiet | The girl is standing on the floor next to the stool | The sister is still encouraging the boy | The girl seems to be laughing | The girl is putting a finger to her lips | The sister is asking for a cookie as well | The girl has one hand up stretched | The girl is asking for a cookie | The girl wants it to be quiet | Her (the girl's) has her finger across her mouth
The woman (mother) is not noticing (paying attention).	The mother is not watching the kids | The mother is not paying attention to anything | The mother doesn't seem to be focusing on the job | The mother is looking out of the window | Mom is obviously in a bit of a daydream | Mom is very much tied up in her own world | The mother is daydreaming | The mother is daydreaming | The mother seems oblivious to what is happening | She does not realise [...] | The mother is oblivious to it | The mother is detached somewhat obviously to her surroundings | The mother is facing away | The mother is not paying attention | The mother is distracted | The mother seems somewhat distracted | The mother is thinking of something else | The mother is looking off into the distance | The mother is looking over a garden | The mother is looking out of the window onto the garden | The mother is looking out the window | The mother is looking out of the window | The woman is gazing out the window | The woman does not appear to notice
There is a garden outside *or some mention of the garden	There is a very nice garden outside, a little curved path and well attended bushes | There is a garden outside | There is a garden outside | There is a garden with trellis | There is a path on the garden | There are plants growing | There is a garden scene with a path and a lawn and some vegetation | There is a tree | There is a garden outside with some shrubs and a bit of lawn and a path | There is a tree in the background | The garden has a path | There are shrubs under the window | The path runs around the corner of the house | There is a lawn to the right to the path with bushes behind it | Outside the window you can see the garden | The garden looks quite neatly manicured | The outlook is to the garden | There is a hedge along the side of the drive | The window is looking out to the garden | Outside the window

	you can see a path and a garden | You could see trees as well | There is a bush next to the path | There is a pathway leading around the corner | There is a tree in the distance through the window and some grass and bushes under the tree | It looks like grass on the other side of the path
The boy is on the stool	The boy has climbed up on a stool | The little boy is standing on a stool | The boy is standing on a stool | The boy is standing on a stool | There is a boy on a stool | The boy is on a stool | The boy is standing on a stool | The little boy has got a stool [to help him reach the cookie jar] | The boy is standing on a stool | The boy is climbing on a stool | The boy is standing on a stool
The are many cupboards in the kitchen *any description of the kitchen	The cookies are on the top shelf | The cupboard door is open | It is a pretty empty kitchen | There are curtains on the window pulled back | There is window with glass squares | The window is open | There are cups and saucers and plates on the side | There is a window | There are curtains held back by ties | There are kitchen cupboards with handles on them | The cookie jar is in an elevated cupboard | There is another dish and two cups beside her on the bench | There are two taps | It's (the tap) not one of those single controls where you mix the hot and cold water | The kitchen window is elevated | There are a few cupboards below | On the place next to the sink are two cups and a plate | The window has curtains | The curtains are pulled back and tied | The {puled back} curtains enable the light to come into the window | The sink is surrounded by two cupboards | There are two cups and a plate on the bench | The cookie jar has its lid off | The hot water tap is in the centre of two turn on off | The open cupboard has a cookie jar | There are dirty dishes on the counter top | There are curtains | The kitchen looks as if it was build in the 1950s | There (i)s two cups and a plate sitting on the bench | There is curtains over the window | There is a few cupboards about six cupboards down below | The cupboard is up high | There is the word cookie jar written on the jar | There is some dried plates on the side | The cupboard door is open | The curtains are open | The window is open | The kitchen looks out to the drive | There are two cups and a plate | The curtains are held back | The lower doors over where the children are don't have any handles nor do the upper drawers apart from the one that (i)s open to get out the cookie jar | The curtains cross in the middle - very fancy | The ruffle on top of the curtain is very ugly | There is some cups on the bench | There is curtains and a window open | The curtains are hanging there | The curtains are parted | The curtains are tied back each side | Next to the sink are two cups an a plate | There is cupboards underneath the sink | The window is open

Appendix C: Transcripts participants who jump in the order

Transcript L2 (lvPPA)

	Events concerning the CHILDREN	**Events concerning the MOTHER**
nonMC	well this is the mother and the two children a boy and a girl	

MC		and their water's running outer {over}
MC	he's going to end up on the floor before he gets the cookie jar	
nonMC		and the water I thought is that one
MC	no he's got cookie in there in his hand	
MC		she's wiping up
MC	I don't know what she's [girl] doing	

Note: MC = main concepts; nonMC = non-main concept; text within [ ] is the intended referents for personal pronouns used in the description; text within { } contains intended meaning of words that were distorted by a semantic or phonological errors or omitted

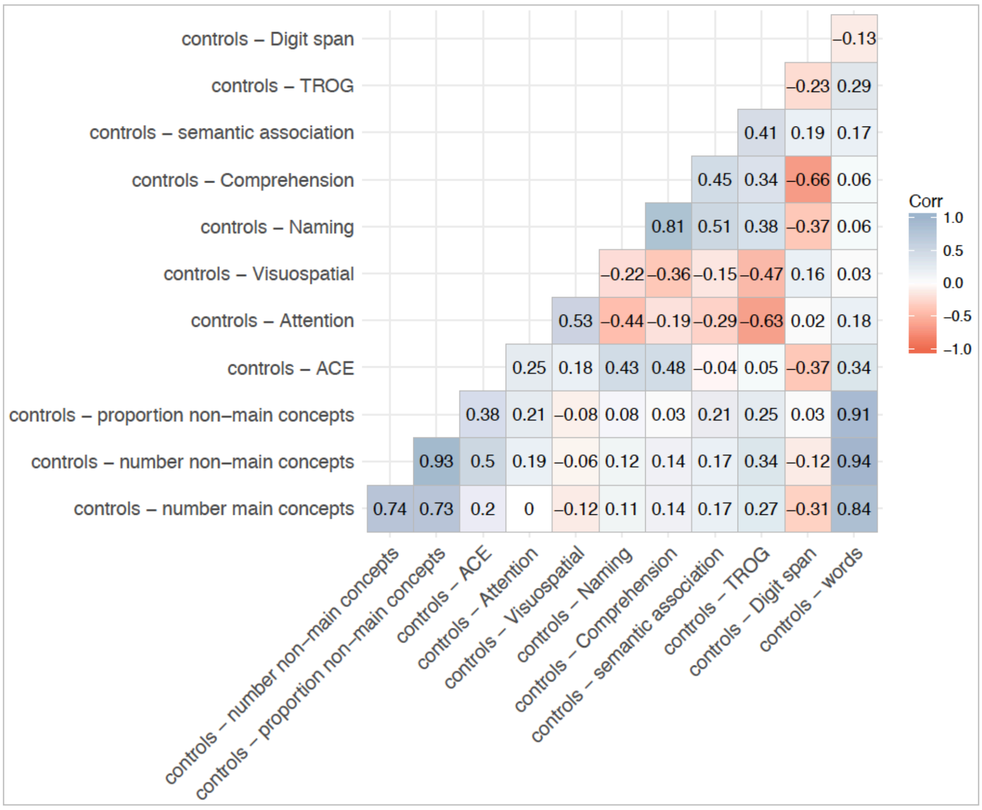
Transcript N11 (nfvPPA)

	Events concerning the CHILDREN	**Events concerning the MOTHER**
nonMC		The mother is has not turned the tap off
MC		the water is spilling on the floor
MC	The boy is about to fall off the stool	
MC	taking the buiscuit	
MC	and handing it to his sister	the mother is drying the pla- plate
MC		she is looking out at the garden
MC	the curtains are drawn back	

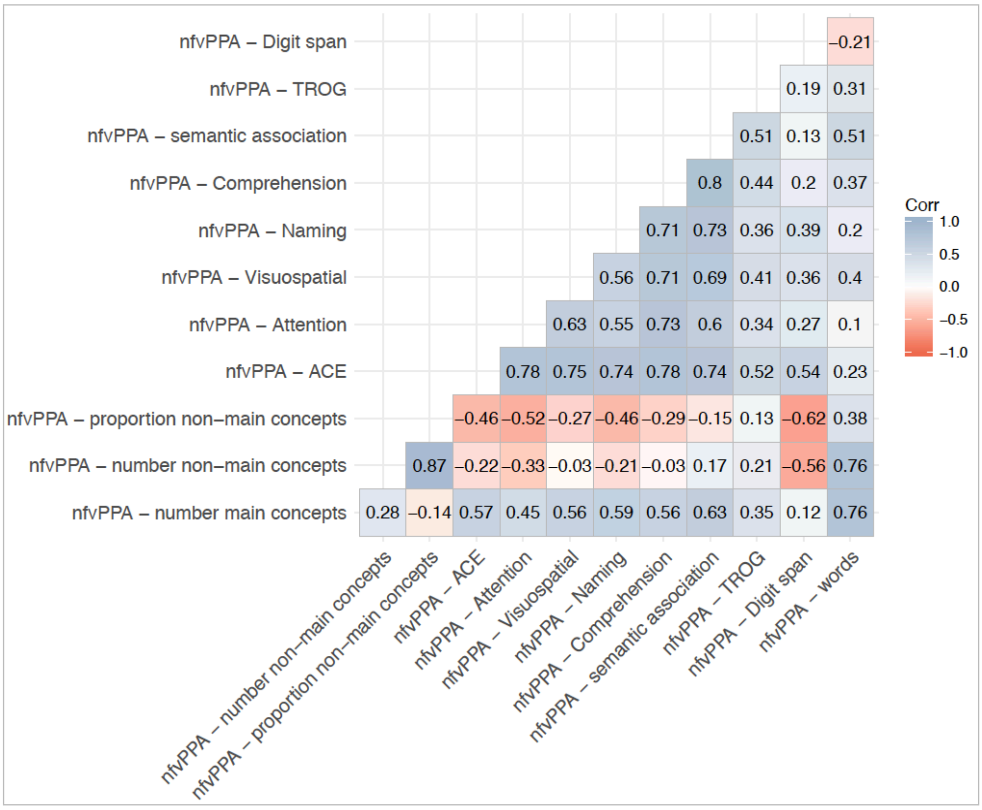
Note: MC = main concepts; nonMC = non-main concept; text within [ ] is the intended referents for personal pronouns used in the description; text within { } contains intended meaning of words that were distorted by a semantic or phonological errors or omitted

Appendix D: Full correlation matrices

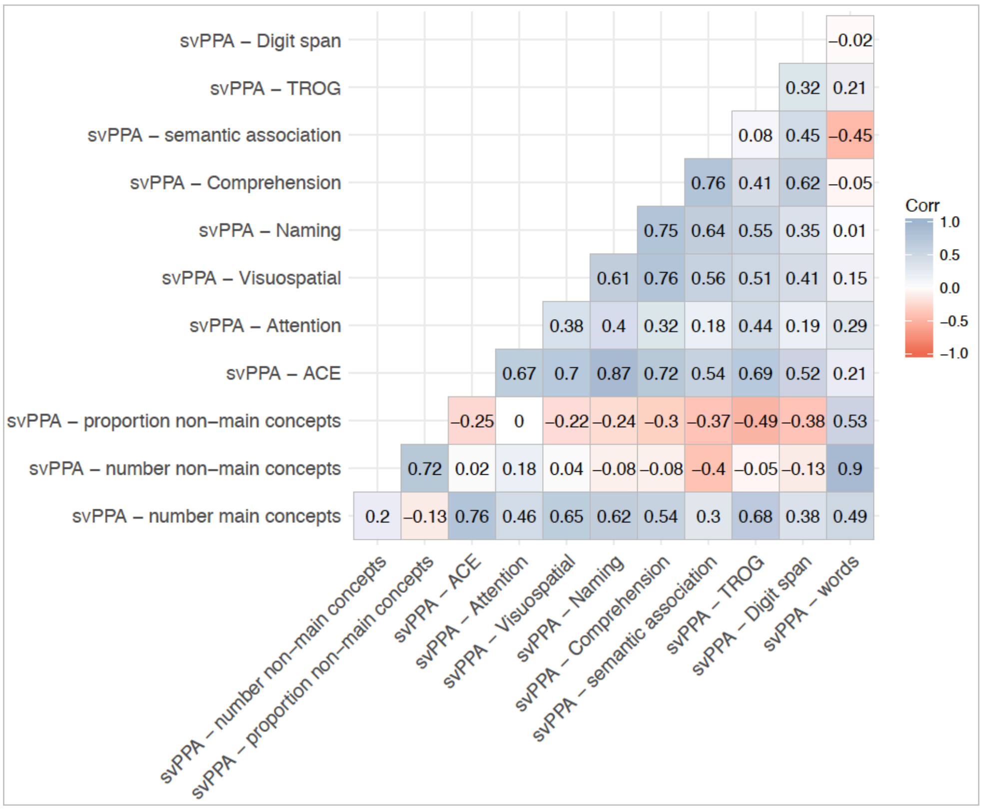
Controls



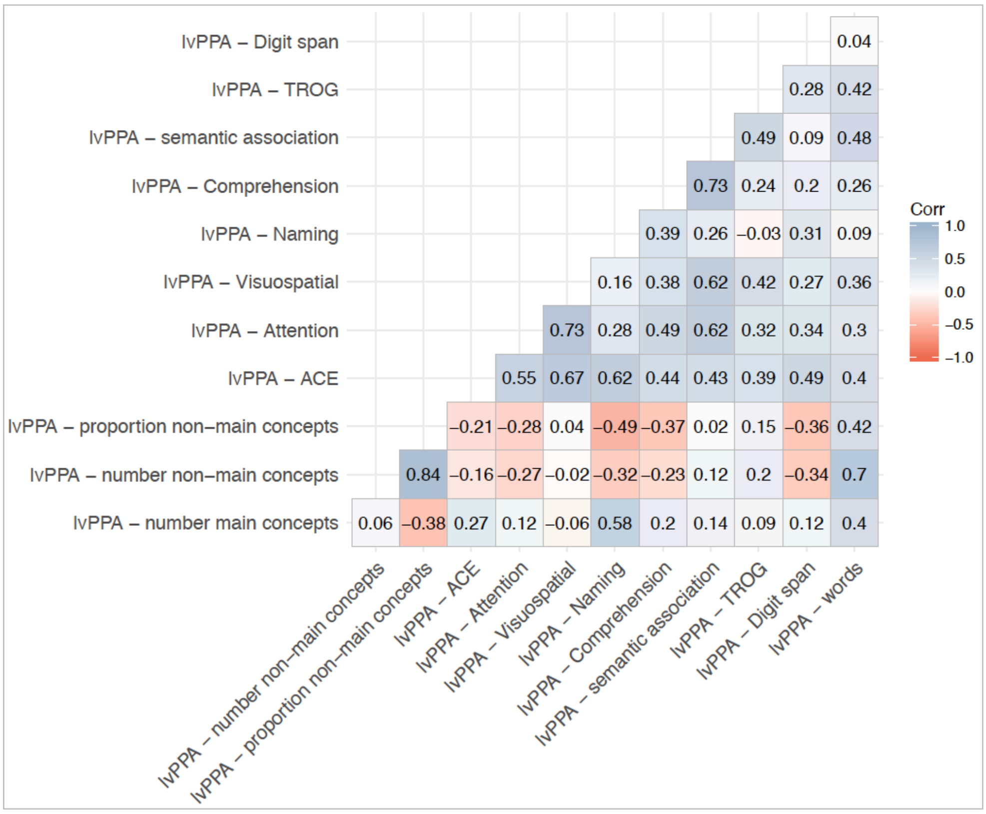
nfvPPA



svPPA


svPPA – Digit span
svPPA – TROG
svPPA – semantic association
svPPA – Comprehension
svPPA – Naming
svPPA – Visuospatial
svPPA – Attention
svPPA – ACE
svPPA – proportion non–main concepts
svPPA – number non–main concepts
svPPA – number main concepts
-0.02
0.32 0.21
0.08 0.45 -0.45
0.76 0.41 0.62 -0.05
0.75 0.64 0.55 0.35 0.01
0.61 0.76 0.56 0.51 0.41 0.15
0.38 0.4 0.32 0.18 0.44 0.19 0.29
0.67 0.7 0.87 0.72 0.54 0.69 0.52 0.21
-0.25 0 -0.22 -0.24 -0.3 -0.37 -0.49 -0.38 0.53
0.72 0.02 0.18 0.04 -0.08 -0.08 -0.4 -0.05 -0.13 0.9
0.2 -0.13 0.76 0.46 0.65 0.62 0.54 0.3 0.68 0.38 0.49
svPPA – number non–main concepts
svPPA – proportion non–main concepts
svPPA – ACE
svPPA – Attention
svPPA – Visuospatial
svPPA – Naming
svPPA – Comprehension
svPPA – semantic association
svPPA – TROG
svPPA – Digit span
svPPA – words
Corr
1.0
0.5
0.0
-0.5
-1.0

lvPPA


lvPPA – Digit span
lvPPA – TROG
lvPPA – semantic association
lvPPA – Comprehension
lvPPA – Naming
lvPPA – Visuospatial
lvPPA – Attention
lvPPA – ACE
lvPPA – proportion non–main concepts
lvPPA – number non–main concepts
lvPPA – number main concepts
0.04
0.28 0.42
0.49 0.09 0.48
0.73 0.24 0.2 0.26
0.39 0.26 -0.03 0.31 0.09
0.16 0.38 0.62 0.42 0.27 0.36
0.73 0.28 0.49 0.62 0.32 0.34 0.3
0.55 0.67 0.62 0.44 0.43 0.39 0.49 0.4
-0.21 -0.28 0.04 -0.49 -0.37 0.02 0.15 -0.36 0.42
0.84 -0.16 -0.27 -0.02 -0.32 -0.23 0.12 0.2 -0.34 0.7
0.06 -0.38 0.27 0.12 -0.06 0.58 0.2 0.14 0.09 0.12 0.4
lvPPA – number non–main concepts
lvPPA – proportion non–main concepts
lvPPA – ACE
lvPPA – Attention
lvPPA – Visuospatial
lvPPA – Naming
lvPPA – Comprehension
lvPPA – semantic association
lvPPA – TROG
lvPPA – Digit span
lvPPA – words
Corr
1.0
0.5
0.0
-0.5
-1.0

CHAPTER 4

The influence of impaired word availability on the macrostructural organisation of speakers with and without language impairments[3]

[3] In preparation for publication: Hameister, I., Nickels, L., Lachmann, G., Schumann, B., Werner, C., Bastiaanse, R. (2018). The influence of limited word availability on the macrostructural organisation of speakers with and without language impairments.

Abstract

Although word retrieval difficulties affect the microstructure of discourse in people with aphasia, the influence of lexical impairments on macrostructural organisation has not yet been evaluated. Consequently, this study investigates the influence of experimentally induced reduced lexical availability on the discourse macrostructure of unimpaired speakers and compares this to the discourse macrostructure of speakers with aphasia.

Forty unimpaired participants were asked to describe complex scenes in two separate sessions with five words central to describing the scenes 'tabooed' for one session. Twelve participants with aphasia described the same set of pictures without any taboo words.

Only 8% of unimpaired participants produced significantly fewer main concepts in the taboo than in the unconstrained condition and only 12% produced more than two changes in the order of concept production. These changes did not affect the overall comprehensibility of the description. In contrast, 58% participants with aphasia produced a significantly reduced number of main concepts and substantial order differences compared to the unimpaired participants. Importantly, 42% people with aphasia showed symptoms that were unusual in controls (e.g., omissions of essential information; temporal sequencing errors).

It is concluded that reduced lexical availability does affect the macrostructure of discourse. However, some participants with aphasia present with macrostructural deficits that cannot be explained by this linguistic impairment alone, implicating a potential event-processing deficit underlying their symptoms.

Introduction

Word retrieval deficits are among the most common symptoms suffered by people with acquired language impairments (e.g., aphasia) and impact significantly on their spontaneous speech production (e.g., Larfeuil & Dorze, 1997; Mayer & Murray, 2003). It is known that the discourse of individuals with word retrieval impairments is frequently interrupted by fillers like "ehm" or long pauses (e.g., Armstrong, 2000) and characterised by semantically and/or phonologically similar word substitutions (e.g., Andreetta, Cantagallo, & Marini, 2012). However, few studies have analysed the macrostructural features of the discourse of people with word retrieval impairments (but see, e.g., informativeness, Andreetta et al., 2012; Huber, 1990; Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, & North, 1983) and none have focused on the interaction of word retrieval deficits and macrostructural impairments. This is the topic of the research presented here.

The macrostructure of our discourse is determined through a speech planning process Levelt (1989) describes as *conceptualisation* and that he proposes involves two main processes: *macroplanning* and *microplanning*.

During macroplanning the general organisation and content of a message is prepared. The speaker first determines a speaking intention. Then he/she selects the required information and orders it in a way that makes it easy for the listener to follow (Levelt, 1989). During microplanning the speaker decides on the perspective of the message and the most appropriate argument structure. By the end of the conceptualisation process, a preverbal message with a more sentence-like structure is generated, that can be further processed in the formulator (Levelt, 1989).

The whole conceptualisation process takes place prior to speech production and requires steady interaction between general cognitive and linguistic processes (Levelt, 1989; Slobin, 1996). Several studies have investigated how acquired language impairments, such as aphasia, might affect conceptualisation (Black & Chiat, 2000; Dipper, Black, & Bryan, 2005; Hameister & Nickels, 2018; Marshall, 2009).

The most commonly reported symptom in the discourse of people with acquired language impairments is a reduction in the amount of essential information produced (Christiansen, 1995; Hameister & Nickels, 2018; Huber, 1990; Marshall, Pring, & Chiat, 1993). In addition, some studies have observed increased production of seemingly irrelevant information (e.g., descriptions of details; Cairns, Marshall, Cairns, & Dipper, 2007; Dipper et al., 2005; Marshall et al., 1993) and an unusual and/or erroneous ordering of information (Carragher, Sage, & Conroy, 2015; Hameister & Nickels, 2018; Manning & Franklin, 2016). However, the underlying nature of these macrostructural symptoms remains largely unclear.

We have previously argued that conceptualisation impairments could directly affect the macrostructural organisation of discourse (Hameister & Nickels, 2018). These impairments could include difficulties understanding the depicted scene, which in turn, makes it difficult for participants to select the most appropriate information and/or conceptualise links between the individual information units (Ash et al., 2006; Hameister & Nickels, 2018). Alternatively, other participants may struggle to focus or maintain their attention on the main information they want to convey, leading to essential information being omitted and/or mentioned in an illogical order.

In contrast, rather than a primary impairment of conceptualisation, Black and Chiat (2000) suggest that it is the linguistic impairments of people with aphasia that affect their ability to conceptualise, in turn, leading to macrostructural deficits. The preverbal message generated in the conceptualisation process needs to be very specific to facilitate the selection of correct words and the most appropriate argument structure (Levelt, 1989; Levelt, Roelofs, & Meyer, 1999). Black and Chiat (2000) argue that language impairments, such as aphasia, lead to impaired access to linguistic information which creates an underspecified preverbal message. Hence, the preverbal message that reaches the formulator is not informative enough to produce a correct statement (e.g., difficulties in perspective-taking; Black & Chiat, 2000; Dipper et al., 2005). Apart from impairments at the sentence level (e.g., Byng, Nickels, & Black, 1994; Cairns et al., 2007; Dipper et al., 2005; Marshall, 2009), this may also result in macrostructural deficits (e.g., Carragher et al., 2015; Hameister, Foxe, Hodges, Piguet, & Nickels, 2018; Hameister & Nickels, 2018).

Finally, some authors, such as Christiansen (1995) and Andreetta et al. (2012), have argued that macrostructural symptoms could be caused by word retrieval difficulties. For example, Christiansen (1995) suggested that some individuals with aphasia produce less essential information because they are unable to access the necessary words. In line with this theory, individuals may also cope with their word retrieval deficits by mentioning information units in the order in which the lexical items can be accessed, regardless of the causal and/ or temporal relations between them (e.g., Hameister et al., 2018; MacDonald, 2013).

Although word retrieval difficulties have been argued to be one of the most plausible underlying mechanisms for macrostructural impairments, this hypothesis has not yet been investigated in detail. However, testing this hypothesis is important to improve the differential diagnosis of the cause of macrostructural impairments in people with acquired language impairments. For example, eliciting aphasia-like symptoms in unimpaired speakers provides a good opportunity to investigate the impact of these impairments in a controlled setting (e.g., Moses, Nickels, & Sheard, 2004) and enables us to refine our hypotheses about mechanisms underlying aphasic symptoms. These hypotheses can subsequently be tested in a clinical population (e.g., Hodgson & Lambon Ralph, 2008).

Previous studies have mainly used paradigms that apply time pressure to decrease the participants' language processing control (Hodgson & Lambon Ralph, 2008; Moses et al., 2004). As an alternative, Meffert et al., (2011) elicited trouble indicating behaviour (e.g., self-corrections of erroneous utterances) in the discourse of unimpaired speakers by restricting their choice of words. They asked their participants to describe a series of complex black and white drawings (e.g., a circus scene) in which multiple unconnected events were happening at the same time (e.g., playing a saxophone, feeding an elephant, watching some tigers; see Meffert et al., 2011, p.311) without using five seemingly essential words (e.g., tiger, circus, elephant, clown, saxophone; Meffert et al., 2011). As expected, these induced word retrieval difficulties caused an increase in trouble indicating behaviour including self-interruptions and self-corrections.

In the current study, we use Meffert et al.'s (2011) taboo paradigm to investigate the influence of limited word availability on the amount and sequence of essential information produced in the complex picture descriptions of unimpaired speakers and participants with aphasia. Based on the idea that a reduced amount and unusual order of essential information might be the result of an underlying lexical impairment we hypothesise that:

1) Unimpaired participants will produce a reduced amount of essential information (main concepts) and show changes in the main concept order when their word availability is experimentally restricted as compared to their unconstrained descriptions
2) Participants with word retrieval impairments will produce a reduced number and unusual order of main concepts compared to unimpaired participants

In Experiment 1 we examine the impact that the taboo paradigm has on the macrostructure of unimpaired participants. In Experiment 2, we compare the macrostructural symptoms that arise in the experimentally-induced word availability difficulties of unimpaired participants to the macrostructural deficits in participants with word retrieval difficulties as part of their aphasic symptom pattern. Both experiments allow us to gain more detailed insight into the influence of impaired word availability on the macrostructural organisation of discourse.

Experiment 1: Macrostructural changes in unimpaired participants with experimentally-elicited impaired word availability: The Taboo Paradigm

General Method

Participants

Forty German native speakers (29 female, mean age: 32.6 years SD: 13.3) with no history of neurological, language, cognitive or uncorrected visual impairments were recruited for Experiment 1. The participants were split in two cohorts. The first 20 participants were assigned to Cohort 1, while the following 20 participants were assigned to Cohort 2.

Materials

Three black and white line drawings were created, each of which depicted a complex scene that aimed to elicit a narrative-like picture description: “Restaurant” (see Figure 1), “Birthday” and “Camping” (see Appendix A). Each picture contained up to three animate entities and two connected main events (e.g., Restaurant scene ‘jacket is burning’ - ‘fire will be put out’).

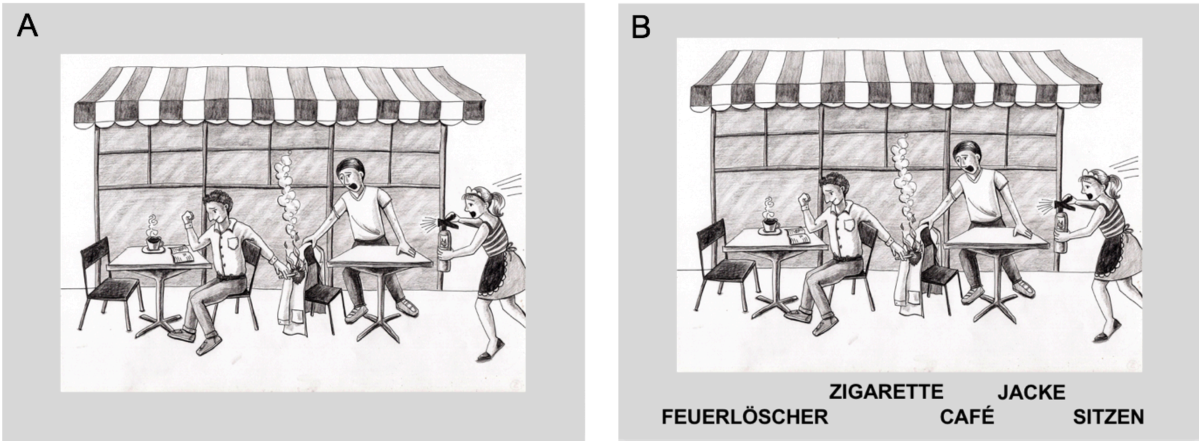


Figure 1: Panel **A** - Example of a stimulus picture as presented in the picture description task without constraints, Panel **B** - the same stimulus picture as presented in the picture description task with tabooed German words (left to right: fire extinguisher, cigarette, café, jacket, sitting)

To simulate the effects of word retrieval difficulties in unimpaired speakers we implemented a modified version of the taboo paradigm first reported by Meffert and colleagues (2011): For each picture the four specific nouns and one specific verb that were most frequently mentioned by Cohort 1 were selected as ‘taboo words’ that participants should not use during the taboo description. The taboo words we identified for the target pictures ‘Birthday’; ‘Camping’ and ‘Restaurant’ are listed in Table 1.

Table 1: Taboo words identified for the target pictures ‘Birthday’; ‘Camping’ and ‘Restaurant’ and their English translations.

Birthday		**Camping**		**Restaurant**	
German	[*English*]	German	[*English*]	German	[*English*]
kommen	[*coming*]	kochen	[*cooking*]	sitzen	[*sitting*]
Kuchen	[*cake*]	Hund	[*dog*]	Feuerlöscher	[*fire extinguisher*]

Mutter	[*mother*]	Topf	[*pot*]	Zigarette	[*cigarette*]
Geburtstag	[*birthday*]	Zelt	[*tent*]	Café	[*café*]
Geschenk	[*present*]	Suppe	[*soup*]	Jacke	[*coat*]

Procedure

All participants completed two sessions, at least 14 days apart, in which they were asked to: *Describe the target pictures by telling a story with a beginning, a middle and an end* (see also Olness, 2006). The examiner gave an example, using the 'Cookie Theft' picture (Goodglass, Barresi, & Kaplan, 1983), to illustrate the required structure and length of the picture descriptions.

The order of conditions was counterbalanced across participants: Participants in Cohort 1 were asked to first describe the pictures (without any constraints). As explained earlier, this was necessary to determine the taboo words for the second testing condition. Consequently, Cohort 1 performed the taboo descriptions in the second test session. In contrast, participants of Cohort 2 produced the picture description in the taboo condition before producing the unconstrained description in the second test session.

All picture descriptions were audio recorded and subsequently orthographically transcribed by the two authors of this paper (IH & GL). Twenty percent of the picture descriptions were transcribed by both authors. There was 98% agreement (4555 words out of 4625) in the transcriptions with only minimal disagreement (e.g., missing articles) that did not affect the main content of the picture descriptions and were resolved by consensus.

Analysis approach

One of the most reliable ways to analyse the macrostructure of discourse is the analysis of main concepts (Linnik, Bastiaanse, & Höhle, 2016; Nicholas & Brookshire, 1995; Richardson & Dalton, 2016). Main concepts represent the most essential information for a particular discourse task (i.e., picture description). Therefore, the number of main concepts provides a valid measure of information selection. The exact definition of a main concept varies between approaches (Capilouto, Wright, & Wagovich, 2005; Nicholas & Brookshire, 1995; Richardson & Dalton, 2016). Here, we follow Nicholas and Brookshire's definition in which a main concept conveys "essential information portrayed in the stimulus picture" (Nicholas and Brookshire, 1995, p.148) and contains "one and only one verb" (p.148).

We additionally investigate the order in which main concepts are mentioned in the participants' picture descriptions. This analysis enables us to understand how individual depicted events are linked in discourse and assess possible temporal and/or causal sequencing errors (Hameister & Nickels, 2018).

Hence, we conducted two separate analyses to investigate the macrostructural organisation of the participants picture descriptions:

1) Analysis 1 - Identification and Number of main concepts
2) Analysis 2 - Order of main concepts

We present the Method, Results and Discussion separately for each individual analysis.

Experiment 1: Analysis 1 - Identification and Number of main concepts

Method

Based on the unconstrained picture descriptions of Cohort 1, we identified main concepts for each target picture.

First, every phrase the participants produced in their picture descriptions was listed. Two individual raters (GL, IH) identified phrases that conveyed a similar meaning in all picture descriptions (e.g., "The man smokes a cigarette" = "The man is smoking") and classed these as a single 'concept' (e.g., "The man is smoking"). The raters agreed in their judgement for 87% of the statements and disagreements were resolved by consensus.

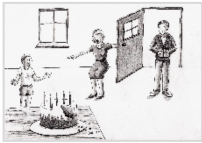
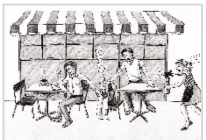
Following Nicholas and Brookshire's (1995) main concept analysis approach we identified every concept that was mentioned by at least 70% of the participants (14/20 participants) as a *main concept*. Hence, each main concept represents an essential piece of information that is central for describing the story represented by the picture.

The number of main concepts each participant produced for each target picture was summed and the difference between the unconstrained and taboo description conditions was analysed using paired t-tests. Moreover, we investigated whether there was an influence of testing order by comparing the picture descriptions of Cohort 1 versus Cohort 2 in each condition (Independent t-test). At an individual level, we used McNemar's test for paired nominal data to statistically analyse which of the participants showed a significant change in the number of main concepts he/she produced in the unconstrained condition compared to the taboo description.

Results

We identified a total of 55 concepts and 17 main concepts across all three target pictures (List of main concepts, see Table 2).

Table 2: Main concepts and order of main concepts identified for each of the three target pictures and the percentage of participants who mentioned each individual main concept.

	Median order	Main concepts	Cohort 1		Cohort 2		Aphasia
			Uncon-strained (%)	Taboo (%)	Uncon-strained (%)	Taboo (%)	
		Birthday					
	1	**It's someone's [mother, boy, father, brother] birthday***	100%	100%	95%	75%	58%
	2	A guest / someone [father, brother] arrived/ is standing in the door	75%	65%	50%	55%	58%
	3	**The boy already took a piece from the cake***	100%	95%	95%	95%	67%
	4	**The mother is angry/ the mother yells at the boy***	100%	90%	90%	85%	58%
		Camping					
	1	**Two boys went camping/ the boys are on a camping trip***	100%	100%	90%	95%	83%
	2	The boys are cooking dinner/ soup/ something	95%	95%	100%	100%	75%
	3	The boys are talking to each other/ are distracted	85%	65%	90%	70%	17%
	4	The dog knocks the pot over	80%	90%	85%	65%	92%
	5	The hot food will hit the boy/ splashes on his feet/ The boy will probably burn himself	80%	80%	85%	85%	42%
		Restaurant					
	1	The men are sitting in a café	95%	95%	95%	100%	50%
	2	The man/smoker is drinking a coffee	80%	60%	85%	70%	8%
	2	The man/smoker is reading a book/magazine	90%	85%	95%	80%	33%
	3	The man/smoker is smoking a cigarette	85%	85%	85%	70%	50%
	4	The man/smoker does not notice anything	80%	65%	65%	50%	25%
	5	**The man/smoker sets the coat of another patron on fire***	100%	100%	100%	90%	92%
	6	The other patron notices the fire/ jumps up/ screams/ *is reacting	70%	35%	65%	60%	8%
	7	**The waitress comes with a fire extinguisher/ puts out the fire***	100%	100%	100%	100%	75%

Note: Essential main concepts (concepts mentioned by 100% of Cohort 1 participants in unconstrained description) are highlighted in bold and marked with a star (*)

The number of main concepts produced per participant and condition is displayed in Figure 2. Statistical analysis showed that the participants produced significantly fewer main concepts in their taboo descriptions (mean: 13.83 (± 2.30) than in their unconstrained picture descriptions (mean: 14.95 (± 1.80); t=-3.38; p =.002), with half of the participants showing numerically fewer main concepts during the taboo description (10 participants in each cohorts). When analysing the cohorts separately, this was significant for Cohort1 ($taboo_{mean}$: 14.25 (±1.80) & $unconstrained_{mean}$: 15.25 (±1.55); t= -2.48; p=.022) and Cohort2 ($taboo_{mean}$: 13.4 (±2.68) & $unconstrained_{mean}$: 14.65(±2.01); t= -2.33; p=.031). Nevertheless, at an individual level, only three participants (C13 of Cohort1; C31 & C32 of Cohort2) showed a significantly reduced number of main concepts in the taboo condition (more than 5 main concepts omitted; McNemar: C13: p=.03; C31: p=.03; C32: p=.008).

Importantly, we found no significant difference in the number of main concepts produced by Cohort 1 and Cohort 2 in the unconstrained (t= 1.06; p=.30) and the taboo description (t = 1.178; p=0.25), indicating that there was no effect of the order in which the tasks were performed on the number of main concepts produced.

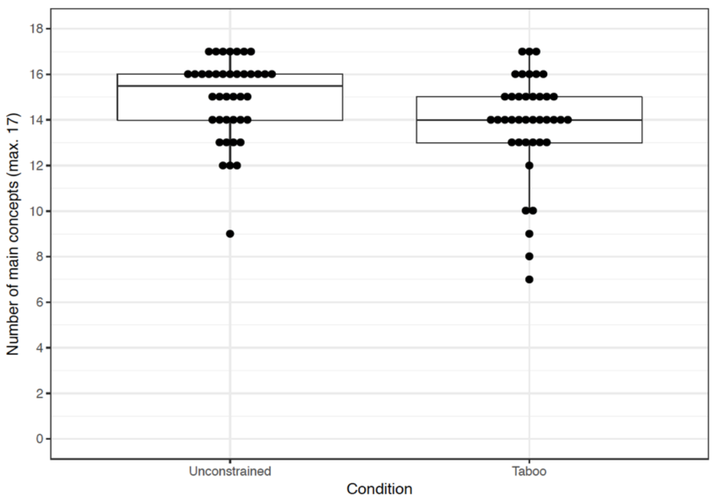


Figure 2: Number of main concepts each individual participant produced in the unconstrained and taboo picture description
Note: The band inside the box represents the median, the box encloses the middle two quartiles of the data.

Interestingly, the main concepts that were mentioned by every participant in Cohort 1 in their unconstrained picture description (hereafter: essential main concepts) were rarely omitted in their taboo descriptions (see Table 2): Only two Cohort 1 participants omitted any of these essential main concepts in a taboo description and only one (P13) omitted more than one essential main concept. In contrast, seven participants from Cohort 2, the group that started with the taboo description, omitted at least one main concept in their taboo picture descriptions, one of whom omitted more than one essential main concept (P32).

Participants seemed particularly likely to omit essential concepts in 'Birthday' scene, which was the first scene they had to describe. Of the participants who omitted essential main concepts, both participants from Cohort 1 and five of the seven from Cohort 2, omitted them in the 'Birthday' scene.

Interestingly, 62% of the main concepts omitted during the taboo descriptions did not necessarily require any of the tabooed words (see Appendix B). For example, the main concept '*the patron jumps up and screams*' from the 'Restaurant' scene was mentioned by 27 (68%) of participants during the unconstrained description, while only 19 participants (48%) mentioned this idea in their taboo description, even though none of the taboo words for the 'Restaurant' scene (sitting, fire extinguisher, cigarette, café, coat; see Table 1) are required to produce this main concept.

Discussion

The results of this first analysis seem to support the hypothesis that impaired lexical availability influences the number of main concepts produced in discourse (Andreetta et al., 2012; Christiansen, 1995): significantly fewer main concepts were produced in the taboo description than unconstrained conditions. Half of the participants in our sample showed the overall tendency to reduce their number of main concepts in their taboo description. As Christiansen (1995) proposed, this suggests that individuals reduce their speech output and overall informativeness as a strategy to deal with impaired word availability. Therefore, it is plausible that some participants with aphasia cope with their linguistic impairments in a similar way (e.g., Andreetta et al., 2012; Christiansen, 1995; Huber, 1990).

Only three unimpaired participants produced significantly fewer main concepts in their taboo description. This suggests that the omission of many main concepts (here: 5 or more), is unlikely to occur as the result of limited word availability.

Moreover, 62% of the omitted main concepts could have been produced without any of the taboo words. Hence, participants did not just simply leave out statements that could only be produced using the taboo words (e.g., Andreetta et al., 2012; Christiansen, 1995). This is surprising given that the participants perceived the taboo description task as very challenging, as demonstrated in comments they made during the testing session: e.g., P26: “fire extinguisher - oh my god, how should I avoid saying that. That is really bad ehm … ehm... man this task is really difficult”). Therefore, omitting statements they were unable to produce without difficulties would have been a plausible strategy to reduce their cognitive load and finish their descriptions quickly.

Interestingly, the participants rarely omitted statements they perceived as absolutely essential to convey the events on the picture. However, most of these essential main concepts contained taboo words, which made their production more difficult. The fact that the majority of unimpaired participants still produced them, suggests that the perceived importance of a main concept may constitute an additional crucial factor in the information selection process. A similar tendency to produce at least the most central ideas in a picture description was also reported for participants with aphasia (Hameister & Nickels, 2018).

We also observed that more participants from Cohort 2 than from Cohort 1 omitted essential main concepts in their picture description. It is possible that describing the pictures once before the taboo description made it easier for the participants of Cohort 1 to cope with the limited word availability. In contrast, participants in Cohort 2 may have been more disrupted in their discourse and aimed to reduce the cognitive load as much as possible by omitting main concepts. This hypothesis is supported by the fact that the omission of main concepts occurred primarily in the first picture description at the beginning of the task when cognitive load for this novel task would be at its greatest.

Two of the participants did omit more than one of the most essential main concepts. Interestingly, these participants seemed to have particular difficulties finding strategies to cope with the restricted word availability and showed clear signs of frustration about the task. One participant (P32) showed the largest decrease in her number of main concepts (unconstrained = 14 main concepts; taboo = 7 main concepts) and also omitted two essential main concepts. She stated "I am not allowed to say more" to justify her very short taboo descriptions. Hence, an individual's persistence in coping with this challenging task, as well as the extent to which they have the linguistic flexibility and creativity required to find strategies to circumvent the use of the taboo words, constitute additional factors that we suggest influence information selection.

In summary, this first analysis showed that reducing the number of main concepts was a common strategy to cope with reduced word availability. However, we also identified additional factors, such as the centrality of each main concept for the picture description or the participants' persistence in dealing with challenging tasks, that influenced the participants' information selection.

Our findings also indicate that analysis of the number of main concepts alone is not sufficient to evaluate participants' information selection performance and should always be complemented by more detailed analysis of the content that is conveyed by the main concept as well as their relevance for the task.

Experiment 1: Analysis 2 - Order of main concepts

Sequencing information appropriately is essential to form a coherent discourse (Levelt, 1989; Manning & Franklin, 2016). Some participants with aphasia have been reported to show difficulties to temporally and/or causally order the content of their discourse in a similar way as controls. Word retrieval deficits have been suggested as a possible explanation for these symptoms (e.g., MacDonald, 2013). If limited word availability affects the macrostructural organisation of discourse in general, we may expect that even unimpaired participants produce some changes in the order of main concepts between the unconstrained and taboo condition. This hypothesis is investigated here.

Method

We first identified the order of main concepts each participant produced in his/her unconstrained picture descriptions, by assigning the number 1 to the main concept that was mentioned first, the number 2 to the main concept that was mentioned second and so on. We then calculated the median position of each main concept for the three target pictures. This allowed us to establish a 'median main concept order' for the description of the three picture stimuli (see Table 2; also see analysis of main concept order in Hameister & Nickels, 2018). Please note that the main concepts 'the man is drinking a coffee' and 'the man is reading a book' of the 'Restaurant' picture share the second position (median position of both main concepts 2.5). Therefore, we only assigned seven positions to the eight main concepts we identified for this picture stimulus.

To identify possible order differences between the unconstrained and the taboo picture descriptions, we analysed the number of position changes that occurred for each participant for each picture. If a main concept that was produced in one session, was omitted in the other, we analysed if the remaining main concepts changed in their positions relative to each other. For example, if a participant's main concept order in the unconstrained description was A-B-C-D-E and changed to A-C-D-B in the taboo description, only the main concept B has changed its relative position (now mentioned after C and D instead of before; but still mentioned after A). The relative position of the other main concepts remained the same (A is still before C & D; C still before D). Concept E is omitted in the second session and is therefore disregarded for the order analysis. Consequently, we score two position changes.

Since not all the participants produced the same number of main concepts, the number of possible position changes varied across participants. For example, if someone produced 8 main concepts in the 'Restaurant' scene, he/she could have made a maximum of 28 possible position changes (totally reversed order). A participant who only produced four main concepts, however, could have only produced a maximum of six position changes. To control for this variability, we calculated a Difference-in-Order ratio. Here, we divided the number of position changes produced by the number of possible position changes. A more detailed description and examples of how the Difference-in-Order ratio is calculated are reported in Hameister & Nickels (2018).

We summed the number of produced and possible position changes over all three target pictures and calculated a total Difference-in-Order ratio for each participant which was analysed in a one-sample t-test, testing the hypothesis that there was a change in order that was statistically greater than zero (indicating that significant order change had occurred).

Results

There was substantial agreement in the participants' main concept order for all three target pictures. The median main concept order for each of the three target pictures (see Table 2) represents the most logical temporal and causal order of events for each target picture as produced by the participants. The participants produced 76% of their unconstrained and 83% of their taboo picture descriptions in this median order.

At the group level we found that the Difference-in-Order ratio was significantly different from 0 ($t = 5.13$, $p < .001$) implying that the main concept order differed between the taboo and unconstrained conditions. Examining the change for each participant, half of the participants produced exactly the same order of main concepts in both picture descriptions (see Figure 3).

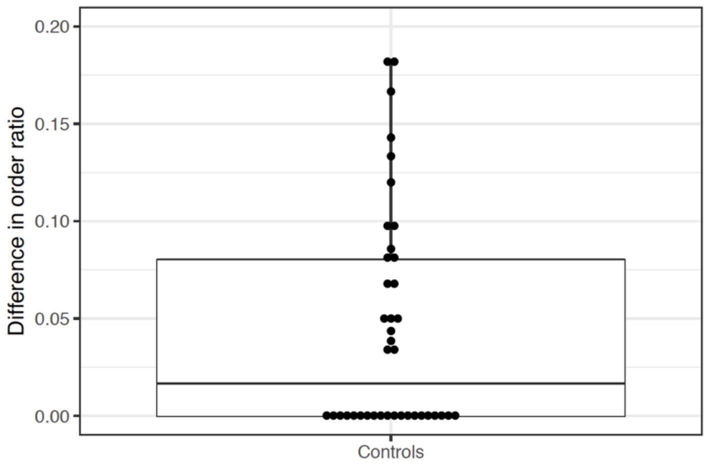


Figure 3: Difference-in-Order ratio across all three target pictures for unimpaired participants

Note: The band inside the box represents the median, the box encloses the middle two quartiles of the data.

Eleven participants (28%) produced a maximum of one position change per target picture. However, the nature of this change resulted in no impairment to the overall comprehensibility of their description. For example, during the taboo description P27 seemed to communicate the correct temporal order by mentioning the events in the order in which they happened (see Table 3). Even though P27 changed the order of main concepts in the unconstrained description, she maintained the temporal order by using more complex syntactic structures linked with conjunctions (e.g., because). All the order changes of these eleven participants were of this type.

Table 3: Example of minimal order changes (1 position change) - participant P27 (Cohort 2) - Restaurant scene

Session1 - Taboo Taboo words: fire extinguisher, cigarette, café, coat, sitting	**MC**	**Session2 - Unconstrained**	**MC**
[…] Touches the parka *with the burning thing so that it catches fire*		[…] the *neighbour jumps up*, because he notices …	
The man who owns the parka *jumped up and screamed* […]		…the guy next to him *burned his coat with his cigarette* […]	

Note: italic= statements identified as a main concept; *MC* = main concept, the *icons* represent the content of the main concept and are included to facilitate the identification of order changes for the reader

Overall, we identified only five participants who produced more than two position changes. These participants were different from those who omitted more than one essential main concept in the previous analysis. The most extensive change of five position changes for one target picture was observed for P22 who produced a main concept order equal to the median concept order we identified for the 'Restaurant' scene during the taboo condition (see Appendix B). In contrast, her unconstrained description in the second test session showed considerable changes (see Table 4).

Table 4: Example of largest order change (5 position changes) - participant P22 (Cohort 2): 'Restaurant' scene.

Session1 - Taboo Taboo words: fire extinguisher, cigarette, café, coat, sitting	**MC**	**Session2 - Unconstrained**	**MC**
A man is in a restaurant		*Two men are sitting outside of a café* in summer	
and reads a book and is totally absorbed in the story.		and both *drank a coffee*	
The man drinks a coffee		One of them is done and would like to leave. He paid,	
and doesn't notice that		*comes back to his seat and discovered that his coat caught fire*	
the burning thing in his hand touches the jumper of the neighbour and sets it on fire		Because the man next to him who absent-mindedly had a cigarette - or - he stretched out his hand *with the cigarette and set fire to the coat*.	
He (the neighbour) was quickly on the toilet		*He doesn't even notice*	
comes back and sees that his coat just started to burn.		because he is *so absorbed in the book*.	
The waitress comes running and saves the situation by putting out the flames.		*The waitress came running with a fire extinguisher* and will hopefully be able to put out the fire.	

Note: italic= statements identified as a main concept; *MC* = main concept, the *icons* represent the content of the main concept and are included to facilitate the identification of order changes for the reader

However, as discussed above, these changes in order for P22 were also due to the use of more complex syntax: This enabled her to convey the same temporal order in her unconstrained description that she had during the taboo description. Thus, the changed order did not affect the overall coherence of her picture description. Importantly, none of the participants who produced these more extensive order changes, omitted more than one *essential* main concept.

Discussion

In line with our hypothesis, we observed order changes between the unimpaired participants' picture descriptions in both conditions. Nevertheless, a more detailed analysis of the position changes showed that 31 participants (76%) produced no, or maximally one, position changes in their taboo description. Further, no participant produced position changes that violated the correct temporal and/or causal order of events.

The tendency to produce more of the taboo picture descriptions in the median concept order suggests that the experimentally induced impaired word availability influenced the participants' overall linguistic flexibility. As illustrated in the examples of P27 and P22, some participants used more complex syntactic structures during the unconstrained description in which the main concepts were verbally linked by conjunctions like 'because'. In contrast, the taboo descriptions showed a simpler syntactic structure and main concepts were mostly linked by 'and' or remained verbally unlinked (see Table 3 and 4).

Overall, our results suggest that reduced word availability does influence the exact order of main concepts, possibly combined with the use of simpler sentence structures in some participants. Importantly, however, temporal and/or causal sequencing errors were not observed and, therefore, cannot be considered to be a consequence of reduced word availability.

Experiment 2: Macrostructural deficits in participants with aphasia and word retrieval difficulties

It has previously been reported that some people with aphasia show macrostructural impairments represented by a reduced number of main concepts and an unusual main concept order (e.g., Cairns et al., 2007; Dipper et al., 2005; Hameister & Nickels, 2018). If these symptoms are caused by limited word availability, we would expect a qualitative similarity to the symptoms of the taboo descriptions of controls. This hypothesis also predicts correlations between the word retrieval skills (e.g., measured by action and object naming) of the participants with aphasia and a reduced number of main concepts and/or a large Difference-in-Order ratio. To test these hypotheses, we used the concept analysis previously outlined in Experiment 1.

General Method

Participants

Twelve participants with stroke-induced aphasia (2 female, mean age: 49.3, SD: 13.4) were recruited from the aphasia rehabilitation ward at the University Hospital of the Rheinisch-Westfälische Technische Hochschule (RWTH) in Aachen (Germany). In order to participate in the study, the participants with aphasia needed to have 1) a sub-acute or chronic stage aphasia (≥ 2 months post-onset); 2) profound word finding difficulties in spontaneous speech (as reported by the attending speech pathologist); 3) sufficient comprehension for task instructions (as reported by the attending speech pathologist); and 4) no history of additional neurological impairments (e.g., neurodegenerative disorders) or uncorrected visual impairments (e.g., neglect).

The type of aphasia was determined based on the participants' Aachen Aphasia Test scores using the analysis software AATP 5.0. The sample included four participants diagnosed with Broca's aphasia, three with Wernicke's aphasia, two with Global aphasia and three with amnestic aphasia (see Table 5).

Four participants (BOK, DAS, ULR & ANW) showed relatively mild language impairments represented (Aachen Aphasia Test scores within the top 30% of the normative sample of participants with aphasia). ANB and RMP were presented with severe expressive impairments characterised by recurring utterances (ANB: "si-si-si-sa") and phonemic jargon

(RMP). The language abilities of the remaining seven participants with aphasia were moderately to severely impaired.

Testing procedure

We assessed the participants' verb and noun retrieval using the German version of the *Verb and Action Test* (VAT; Bastiaanse, Wieling, & Wolthuis, 2016) and the Aachen Aphasia Test (AAT) naming subtest (nouns, colours, compound nouns and descriptions of simple situations). We also investigated the participants' conceptual knowledge of events using the *Kissing and Dancing Test* (Bak & Hodges, 2003) and *Event Processing Test* (Marshall, Black, Byng, Chiat, & Pring, 1999). Finally, we asked the participants with aphasia to sort individual pictures into a picture story to investigate their non-verbal information sequencing ability (see Table 5).

All participants with aphasia were asked to describe the three complex pictures used in Experiment 1 ('Birthday'; 'Camping' & "Restaurant' scene) by telling a story with a beginning, a middle and an end. The examiner demonstrated the required form and length of the picture description using the 'Cookie Theft' scene (Goodglass et al., 1983).

Table 5: Demographics and background test results of participants with aphasia in our study. All test scores refer to the number of correct responses, except the Token Test score, which refers to number of errors, the Aachen Aphasia Test also provides the Percentage rank (in parentheses).

		Participants											
		MAD^	ANB^	MAH^	ANS^	RMP^	DAM^	JOK^	TSW	DAS	BOK	ULR	ANW
Demo-graphics	**Sex**	M	F	M	M	M	M	M	M	M	M	M	F
	Age (years)	62	43	49	40	59	47	47	57	52	52	50	40
	Time PO (months)	34	62	23	36	22	12	12	8	16	16	22	3
	Syndrome	B	G	B	G	B	W	W	W	A	A	B	A
Language Measures													
Aachen Aphasia Test (AAT)	**Token Test**	38 (31)	46(13)	38(31)	50(2)	44(19)	47(10)	19(67)	02(97)	4(94)	0(99)	15(74)	13(76)
	Repetition (n =150)	108(48)	58(21)	104(44)	61(22)	28(48)	86(33)	75(26)	48(17)	133(76)	150(99)	138(83)	143(89)
	Writing (n=90)	59(60	11(22)	26(34)	2(12)	5(16)	23(31)	44(47)	50(51)	86(96)	85(95)	74(79)	83(93)
	Naming (n=120)	80(51)	22(21)	57(39)	38(31)	20(20)	61(41)	26(23)	62(41)	104(86)	119 (100)	109(93)	98(77)
	Comprehension (n=120)	71(39)	67(35)	77(47)	76(45)	44(15)	75(45)	96(76)	106(93)	113(99)	118 (100)	101(86)	109(96)
VAST	**Verb Naming** (n=50)	30.5	6.5	17	20	4	15	13.5	37	45.5	42	45.5	45
	Noun Naming (n=50)	40	19	N/A	33.5	7.5	N/A	32.5	N/A	45.5	46.5	48.5	N/A
Measures of non-verbal event processing													
Nonverbal event pro-cessing	**Kissing & Dancing** (n= 52)	N/A	46.5	N/A	30	41	50	51	51	52	50	50	49
	Picture sequencing (n= 80)	73	69	26	54	N/C	76	73	76	79	76	79	79
	Event processing (n= 60)	49.5	51	50	30	36	56	52	55	55	56	57	59

Note: ^ marks participants with a significantly reduced number of main concepts and significant order differences; [a] F = Female; M = Male; [b] PO = months post-onset at the time of admission to the aphasia rehabilitation ward; [c] Syndrome as assessed by the Aachen Aphasia Test: B = Broca's, W = Wernicke's, G = Global, A = Amnestic; Aachen Aphasia Test percentage rank provided in parentheses based on the normative study with individuals with aphasia (Huber, Poeck, & Willmes, 1984) - represents how many individuals with aphasia performed just as well or worse; N/A = no test scores available due to time constraints; N/C test could not be conducted as participants failed example items

Data Analysis

As in Experiment 1, we performed two analyses to investigate macrostructural symptoms in the participants with aphasia:

Analysis 1: Identification and number of main concepts

Analysis 2: Order of main concepts

These analyses were supplemented by correlations between macrostructural features (number and order of main concepts) and the people with aphasia's test performance in non-verbal event processing, word retrieval and non-verbal event sequencing.

Experiment 2: Analysis 1 - Number of main concepts

Method

The participants' picture descriptions were transcribed orthographically. Non-verbal responses such as pointing, writing letters on the table or gestures were added to the transcript.

Two experimenters (IH, GL) identified statements in the participants with aphasia's picture descriptions that represented any of the main concepts previously identified in our unimpaired control sample. Verbal and non-verbal responses were taken into account. The raters' main concept identification showed 97% agreement. The 6 statements on which they disagreed were categorised by consensus.

The number of main concepts each participant with aphasia produced was summed over all three target pictures and compared to the unimpaired control samples from Experiment 1 using Singlims single case statistics (Crawford, Garthwaite, Azzalini, Howell, & Laws, 2006).

We further calculated z scores for our measures of non-verbal event processing (Kissing and Dancing Test; Event Processing $\left(z = \frac{\text{(individual test score} - \text{average test score)}}{\text{standard deviation of test score}}\right)$ Test), word retrieval (VAT action and object naming), and non-verbal sequencing and combined them to extract a single average z score for each area. Since the AAT subtest naming score was not only a measure of single word retrieval but also required the production of simple sentences (e.g., "the man is begging" [der Mann bettelt]) we excluded this test score from our word retrieval measures for this study.

We then calculated Pearson's correlations between the average z scores and the participants' number of main concepts and Difference in Order-ratio. All p-values were corrected for multiple comparisons (Bonferroni correction). Therefore, a p-value smaller than p=.0167 was required to achieve a significant correlation.

Results

The number of main concepts identified in each of the participants with aphasia's picture description varied from 1 to 16. Figure 4 displays these data compared to the unconstrained and taboo descriptions of the unimpaired participants.

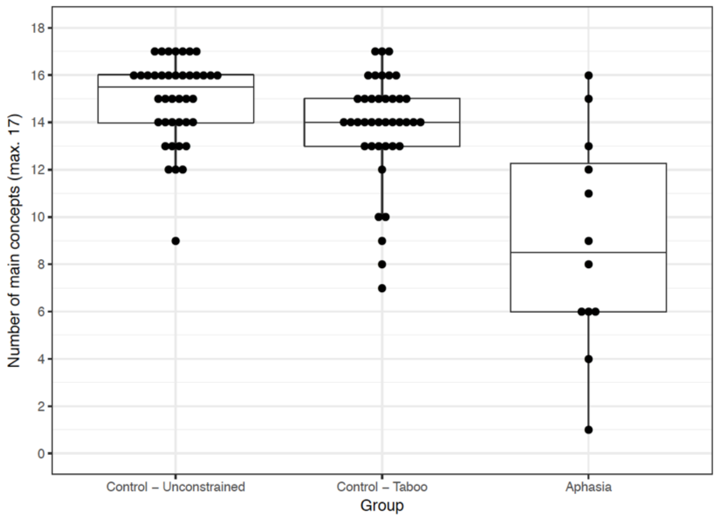


Figure 4: Number of main concepts unimpaired participants (unconstrained and taboo) and participants with aphasia produced across all target pictures

Note: The band inside the box represents the median, the box encloses the middle two quartiles of the data.

Eight participants with aphasia produced significantly fewer main concepts than unimpaired participants produced in their unconstrained descriptions (≤ 11 main concepts, Singlims (Crawford et al., 2006), t= -2.17, *p*=.018). Even compared to the taboo descriptions, we found seven participants with aphasia who showed a significantly reduced number of main concepts (≤ 9 main concepts, Singlims, (Crawford et al., 2006), t= -2.07, *p*=.022).

Each of the essential main concepts was produced by a minimum of 58% of people with aphasia (see Table 2 and Appendix B,). Nevertheless, only three people with aphasia produced all of the essential main concepts in their picture descriptions and five omitted more than one essential main concept.

Analysing the background test results that were associated with the number of main concepts the participants produced, we observed moderately high correlations between number of main concepts and word retrieval, event processing and picture sequencing scores (see Table 6). Nevertheless, these did not reach signficance, most likely due to the small sample size (Goodwin & Leech, 2006).

Table 6: Results of the correlation analysis for the Number of main concepts and order of main concepts

		Total #Main Concepts	Average Difference-in-Order ratio
Event Processing	Pearson's r	0.589	-0.643
	p-value	*0.044*	*0.033*
Word Retrieval	Pearson's r	0.618	-0.736*
	p-value	*0.032*	*0.010*
Picture Sequencing	Pearson's r	0.525	-0.803*
	p-value	*0.080*	*0.003*

**p*<.0167 (significant Bonferroni corrected p-value)

Discussion

Although we observed a significantly reduced number of main concepts in eight participants with aphasia, there were no significant associations between the participants' word retrieval abilities and the number of main concepts. Therefore, our results suggest that it is unlikely that the small number of main concepts in discourse can be fully explained by the reduced lexical availability (e.g., Andreetta et al., 2012; Cairns et al., 2007; Christiansen, 1995; Huber, 1990).

Importantly, people with aphasia, like the unimpaired participants, were less likely to omit the most essential information. This supports our earlier suggestion that the perceived importance of each individual main concept constitutes an additional crucial factor that influences the prioritisation of which conceptual information is produced.

Nevertheless, 5 out of the 12 participants (48%) with aphasia omitted more than one essential main concept, in contrast to only two unimpaired participants (5%, Fisher Exact Test, p=0.005, 1-tailed). The two unimpaired participants were those who indicated considerable frustration throughout the taboo task and seemed to display a reduced ability to find alternative strategies to cope with the limited word availability. Consequently, the omission of more than one *essential* main concept is also unlikely to be explained by lexical impairments alone (e.g., Cairns et al., 2007; Hameister & Nickels, 2018; Marshall, 2009). Potential alternative underlying mechanisms will be further discussed in the General Discussion.

Experiment 2: Analysis 2 - Order of main concepts

Methods

We first identified the exact main concept order each aphasic speaker produced in their picture descriptions of the three target pictures. Then we compared this order to the median main concept order calculated using the methods described in Experiment 1 (Analysis 2) and calculated the overall Difference-in-Order-ratio (DiO-ratio) by summing the number of position changes over all three target pictures and dividing by the number of overall possible position changes.

We statistically compared the Difference-in-Order ratio of each participant with aphasia to the average Difference-in-Order ratio of unimpaired participants using Crawford et al.'s (2006) single case statistics (modified t-tests: Singlims). Similar to the analysis of the number of main concepts, we calculated Pearson's correlations between the Difference-in-Order ratios and the average z-scores of the participants' performance on tests tapping into event-processing, word retrieval and non-verbal picture sequencing to identify possible factors predicting large order differences. All p-values were Bonferroni corrected for multiple comparisons, hence p-values smaller than p=.0167 marked a significant correlation.

Results

Overall, there was considerable variability in the order of main concepts in the participants with aphasia's picture descriptions. There were five participants with aphasia who produced a significantly larger Difference-in-Order ratio than the unimpaired participants (DiO ratio > 0.22; t= 3.033; p=.002). However, it is important to note that when participants produce a small number of main concepts it is easy for a large Difference-in-Order ratio to occur. For example, if only two main concepts are produced, as for participant MAH (see Table 7), the Difference-in-Order ratio can only have a value of 1 (totally reversed) or 0 (correct order).

Table 7: Example transcript of participant MAH's Restaurant scene description, illustrating a reversed order of main concepts (DiO -ratio = 1)

Median order (e.g., P7 - Cohort 1)	MC	MAH - 2 main concepts - Restaurant Scene	MC
The *man is reading a book*.		*cigarette ehm fire*	
At the same time, he *set the jacket of another patron on fire*.		*reading* {points to man}	

Importantly, we observed order changes in some participants with aphasia that were not observed in any unimpaired participant. For example, 6 of the 11 participants with aphasia who indicated that '*the man set the jacket on fire*' in the 'Restaurant' scene, mentioned this main concept at the beginning of their description. In contrast, none of the unimpaired control started their 'Restaurant' description with this main concept.

We observed a similarly unusual main concept order in the 'Birthday' descriptions of two participants with aphasia. JOK and ULR mentioned that *'the mother is angry with the boy'* before the observation that the '*the boy stole a piece of cake',* without linking these information units any further. While some unimpaired participants also produced this unusual order, all of them linked the main concepts by saying *'the mother is angry* ***because*** *the boy already ate a piece of cake'.*

In the analysis of which of the participants' background test results were significantly correlated with their Difference-in-Order ratio, we observed significant correlations with word retrieval: poorer verb and noun retrieval was associated with larger order differences (see Table 6, earlier). Lower scores in the test of non-verbal picture sequencing were also significantly correlated with a larger Difference-in-Order ratio (see Table 6). The moderately large correlation between the participants' event-processing skills and their Difference-in-Order ratio did not survive Bonferroni correction.

Discussion

In line with our previous research (Hameister & Nickels, 2018), the main concept order of some participants with aphasia differed significantly from the median concept order that was observed in unimpaired participants when unconstrained. As for unimpaired participants, we suggest that minimal position changes (1 or 2 position changes) can be explained by underlying lexical impairments. In the unimpaired participants we argued that the increased cognitive load from the taboo task led to simpler syntactic structures resulting in a higher Difference-in-Order ratio. The language impairment of some people with aphasia (including reduced lexical availability) may also result in reduced syntactic complexity and hence an order that is different to the median of the controls in the unconstrained condition. The significant correlation between the word retrieval performance and the Difference-in-Order ratio of participants with aphasia, further suggests that participants with more severe lexical problems were more likely to make more extensive order changes.

In contrast to unimpaired controls, but in line with previous results (Carragher et al., 2015; Hameister et al., 2018; Hameister & Nickels, 2018; Manning & Franklin, 2016), some participants with aphasia are more likely to start their picture description with one of the most essential main concepts, even if this does not correspond to the most appropriate temporal order. For example, six participants with aphasia started their 'Restaurant' description by mentioning that *"the man burned the jacket"*. It is possible that they started with this main concept because the required words were the first that were available to them. However, it may also be the case that they started their descriptions with the concept that was perceived as the most essential, either because they were unable to identify the correct temporal order of events (an event-processing impairment) or because they prioritised expressing the most vital information in the context of as short a description.

In support of the latter idea, we observed that none of the participants who produced "*the man burned the jacket"* in first position, mentioned more than three main concepts in their 'Restaurant' description. Hence, the perceived importance of a main concept seemed to have a stronger influence on the order of main concepts when only very few were produced.

Nevertheless, we observed that the participants' ability to order events non-verbally in the picture-sequencing task was strongly associated with their Difference-in-Order ratio. Interestingly, this task was neither significantly associated with the number of main concepts nor with the participants' naming abilities (see Appendix B for the full correlation matrix). This suggests that lexical impairments alone cannot account for the language changes observed in some people with aphasia.

General Discussion

This research aimed to examine the influence of word retrieval impairments on the macrostructural organisation of discourse. In Experiment 1, we used a taboo paradigm to induce aphasia-like reduced word availability in unimpaired participants and compared this to the performance of individuals with aphasia (in Experiment 2).

Unimpaired participants showed a reduced number of main concepts when they were restricted in their word choice because of the taboo task, compared to unconstrained picture description. However, in contrast to Christiansen's (1995) hypothesis, the unimpaired participants in our sample did not simply omit information they were not able to produce. The experimentally induced reduced word availability rather made them more focussed on production of essential main concepts. Hence, they predominantly omitted less essential main concepts, even though these did not require any of the tabooed words.

Overall, the group of unimpaired participants also produced a different order of main concepts in the taboo description compared to the unconstrained condition. However, none of the unimpaired participants showed temporal sequencing errors. It is possible that the experimentally-induced lexical difficulties were not sufficient to cause such drastic changes to discourse (e.g., Meffert et al., 2011), or, alternatively, that unimpaired participants were able to use their intact language skills to keep the temporal order. The changes we did observe in ordering of concepts could be accounted for by a reduced syntactic complexity in participant's taboo descriptions. This matches reports by MacDonald (2013) who argued that when difficulties in language production are caused, for example, by cognitive deficits, simpler syntactic structures may be produced in order to facilitate the monitoring of speech production.

MacDonald (2013) also proposed that speakers tend to produce utterances in an order that reduces interference between speech planning and speech production. If memory and language production are intact, a speaker is able to easily recall their pre-planned utterances and use them flexibly throughout their discourse. In contrast, if memory or language production is impaired, recall of pre-planned utterances deteriorates and speakers tend to simplify their speech plan and execution (MacDonald, 2013). In line with this report, some of the unimpaired participants in our sample, seemed to have simplified the syntax used in their picture description and described the events in the order in which they conceptualised them.

In this study all participants were asked to describe the picture by telling a story with a beginning, a middle and an end. Despite this particular task practiced with each of the participants, we consider it possible that some participants adhered more to the task than others. As a result, some unimpaired participants may have interpreted the task in a way that resulted in very brief picture descriptions with a more restricted syntactic structure than they would normally produce in their connected speech. The same might be true for some participants with aphasia in our study.

The taboo task clearly restricts word availability and was challenging for the majority of unimpaired participants. However, it could be argued that, while it simulated poor word availability, it is not a precise simulation of the impact of word retrieval in aphasia (Hodgson & Lambon Ralph, 2008; Meffert et al., 2011; Moses et al., 2004). It is true that additional cognitive control is probably required to supress the use of the tabooed words and also that unimpaired participants may have greater linguistic flexibility to circumvent the taboo words (e.g., by paraphrases). Nevertheless, we did observe macrostructural changes in the unimpaired participants' taboo descriptions that resemble, in parts, previously reported symptoms in aphasia, which supports the use of this paradigm as an experimental tool.

In Experiment 2, we examined the performance of people with aphasia on the same task with the same pictures as we used with unimpaired participants. Just like the unimpaired participants under taboo condition, people with aphasia produced fewer main concepts and used a different main concept order However, unlike unimpaired participants, some of the participants with aphasia omitted essential main concepts and made errors in the temporal ordering of the events. Hence, we suggest that lexical difficulties alone cannot explain this symptom pattern that was observed in 5 of the 12 participants with aphasia in this study.

While Experiment 1 only simulated impaired lexical availability, linguistic impairments in aphasia can occur for many reasons. For example, participant ANS, showed poor event-processing skills in combination with a greatly reduced number of main concepts (ANS: 6 main concepts, $z_{event\text{-}processing}$= -2.31), and unusual temporal sequencing. In contrast, his naming performance was the second best of those participants who showed a significantly reduced number of main concepts (see Table 5). This suggests that that the picture description performance of some participants with aphasia may also be influenced by the more general processes that are involved in identifying and understanding depicted events and/or understanding how the events are linked to each other (e.g., Cairns et al., 2007; Hameister et al., 2018; Hameister & Nickels, 2018). ANS' results further suggest that an additional examination of his nonverbal semantic and general cognitive skills, might be fruitful in order to identify the primary cause of his macrostructural deficits and improve targeting of treatment.

We found a high and significant correlation between the participants with aphasia's non-verbal sequencing ability and the degree to which their descriptions differed in order from the norm. This may indicate general non-verbal planning deficits and/or deficits in related executive skills that could underpin the macrostructural symptoms of some participants with aphasia (e.g., Alexander, 2006; Barker, Young, & Robinson, 2017; Schultze-Jena, 2001). However, a more detailed analysis of the participants' performance on non-verbal neuropsychological tests of attention, working memory and executive functions is necessary to follow up on this hypothesis.

Finally, the reduced number of main concepts in people with aphasia may have been also caused by the influence of their linguistic impairments leading to an underspecified message, which in turn impairs their preverbal planning of the description and results in uncertainty in their discourse production (e.g., Black & Chiat, 2000; Cairns et al., 2007; Dipper et al., 2005; Marshall, 2009). A reduced number of main concepts, including the most essential ones, was observed in those people with aphasia who decided to stop their description as soon as uncertainty occurs.

Conclusions

The results of the two experiments reported here suggest that lexical availability has substantial influence on macrostructure. However, in contrast to previous findings, our study showed that lexical difficulties tend to narrow an individual's focus on the most essential information, it is not the case that participants simply leave out the information they cannot find words for (Christiansen, 1995).

We also observed an association between the participants' non-verbal sequencing skills and the order of main concept production, suggesting that the macrostructural symptoms of some of the people with aphasia in our sample might be underpinned by an impairment to more general conceptualisation processes (e.g., Black & Chiat, 2000; Dipper et al., 2005; Hameister & Nickels, 2018).

Whether the participants' linguistic impairments also impair their ability to prepare their picture description pre-verbally (Black & Chiat, 2000; Dipper et al., 2005) or whether more general cognitive impairments (e.g., attention, working memory) affect their macrostructural planning (Schultze-Jena, 2001; Hameister et al., 2018) needs further research.

In summary, our study has demonstrated the influence of lexical availability on the macrostructural organisation of discourse in unimpaired speakers and participants with aphasia and showed that this is not the only source of macrostructural impairment in aphasia.

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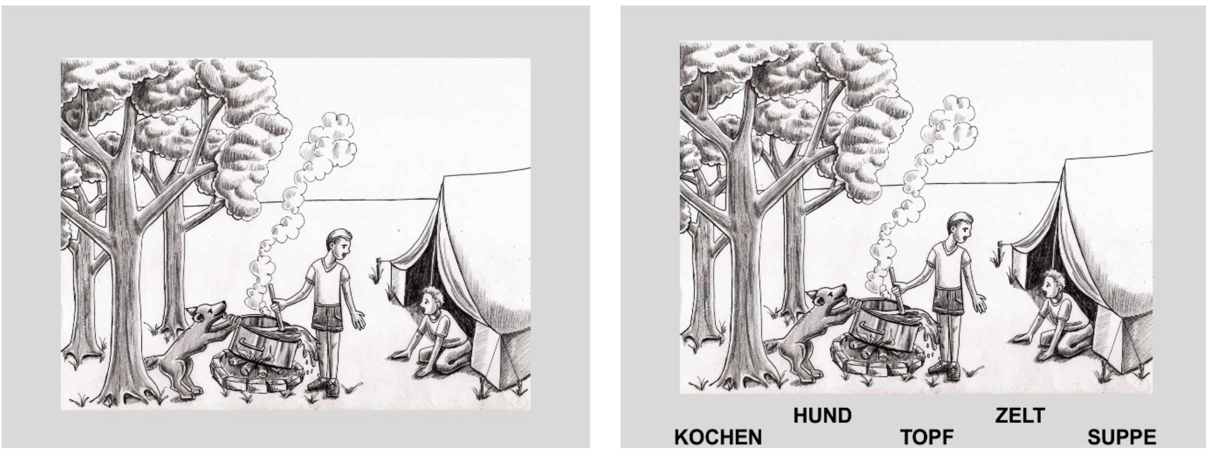
Appendices

Appendix A: Additional material pictures

Birthday Scene (left: unconstrained condition; right: taboo condition)

Taboo words: Kuchen [cake]; Mutter [mother], kommen [coming], Geburtstag [birthday], Geschenk [present]

Restaurant Scene (left: unconstrained condition; right: taboo condition)



Taboo words: kochen [cooking]; Hund [dog], Topf [pot], Zelt [tent], Suppe [soup]

Appendix B: Main concepts and their median order in the three target pictures and percentage of participants of both cohorts who produced these main concepts in each testing session

Main concepts (MC)	Cohort 1 Unconstrained (%)	Cohort 1 Taboo (%)	Cohort 2 Unconstrained (%)	Cohort 2 Taboo (%)	Median order
Birthday					
It's someone's [mother, boy, father, brother] birthday	100%	100%	95%	75%	1
A guest / someone [father, brother] arrived/ is standing in the door	75%	65%	50%	55%	2
The boy already took a piece form the cake	100%	95%	95%	95%	3
The mother is angry/ the mother yells at the boy	100%	90%	90%	85%	4
Camping					
Two boys went camping/ the boys are on a camping trip	100%	100%	90%	95%	1
The boys are cooking dinner/ soup/ something	95%	95%	100%	100%	2
The boys are talking to each other/ are distracted	85%	65%	90%	70%	3
The dog knocks the pot over	80%	90%	85%	65%	4
The hot food will hit the boy/ splashes on his feet/ The boy will probably burn himself	80%	80%	85%	85%	5
Restaurant					
The men are sitting in a café	95%	95%	95%	100%	1
The man/smoker is drinking a coffee	80%	60%	85%	70%	2
The man/smoker is reading a book/ magazine	90%	85%	95%	80%	2
The man/smoker is smoking a cigarette	85%	85%	85%	70%	3
The man/smoker does not notice anything	80%	65%	65%	50%	4
The man/smoker sets the coat of another patron on fire	100%	100%	100%	90%	5
The other patron notices the fire/ jumps up/ screams/ *is reacting	70%	35%	65%	60%	6
The waitress comes with a fire extinguisher/ puts out the fire	100%	100%	100%	100%	7

Note: Order of test sessions: Cohort 1= Unconstrained - Taboo; Cohort 2= Taboo - Unconstrained

Appendix C: Full correlation matrix between background test results (z scores) and number and order of main concepts

		Average # MC	Average DiO-ratio	Event Processing score	Word Retrieval score
Event Processing score	Pearson's r	0.589	-0.643	--	--
	p-value	*0.044*	*0.033*	--	--
Word Retrieval score	Pearson's r	0.618	-0.736 *	0.460	--
	p-value	*0.032*	*0.010*	*0.133*	--
Picture Sequencing score	Pearson's r	0.525	-0.803 *	0.502	0.564
	p-value	*0.080*	*0.003*	*0.097*	*0.056*

Note: * p<.0167 (significant Bonferroni corrected p-value); MC = main concept; DiO = Difference-in-order-ratio

CHAPTER 5

Seeing beyond language: What eye movements can tell us about language conceptualisation and production[4]

[4] In preparation for publication: Hameister, I., Caruana, N., Griffin, Z., & Nickels, L. Seeing beyond language: What eye movements can tell us about language conceptualisation and production.

Abstract

Symptoms of possible conceptualisation difficulties (e.g., inappropriate information selection and sequencing) have been reported in the discourse of some individuals with acquired language impairments (e.g., aphasia). This paper addresses whether eye movements can provide insights into early discourse planning processes and hence facilitate the diagnosis of possible conceptualisation impairments. It aimed to investigate i) whether there was consistency between the eye movements of unimpaired speakers during complex picture description; and ii) whether the eye movements of one speaker with aphasia showed a different pattern, that could be an indication of conceptualisation difficulties.

Six unimpaired participants and one participant with aphasia (STR) described a complex black and white line drawing while their eye movements were recorded. Participants had 10 seconds to inspect the scene before they described the picture. During this Inspection phase, all participants showed the longest fixation on the AOI containing the main agent. Unimpaired speakers showed temporal agreement in their fixation patterns during the inspection phase. Five of the six participants showed early fixations (within first 500ms) to the pre-set area of interest (AOI) containing the critical main event, suggesting early decoding processes during speech planning. In contrast, STR fixated on the critical main event significantly later (after ~4000ms). In the description phase, all unimpaired participants mentioned the agent first during their description. However, for STR the entity mentioned first was consistently produced at the end of unimpaired participants' descriptions. These data suggest a difference in STR's speech planning and/or plan execution. This motivates the potential for eye-tracking to be used to investigate conceptualisation processes and their possible impairments.

Introduction

"Where words are restrained, the eyes often talk a great deal"

Samuel Richardson (1689-1719, English writer and printer)

Every day, individuals with acquired language impairments experience just how much the inability to find and produce the right words can prevent them from saying what they want to say. Individuals often describe this experience in a similar way. For example, STR, the man with aphasia whose data we will be presenting in this paper, reported "It is all there in my head, but I can't say it". The study reported here aimed to evaluate whether the analysis of eye movements can be used to provide more specific information about the process of discourse planning even when individuals are not able to appropriately realise this discourse in speech production.

Organising our thoughts in a way that we can verbally express them is the first step of speech production. This process is known as *conceptualisation* (Levelt, 1989) and comprises two main processing steps: *macroplanning* and *microplanning*. During macroplanning the general structure of a message is determined. First, the speaker forms a speaking goal. Then he/she decides which information needs to be selected and how it should be ordered to achieve this goal. During microplanning, the message is prepared for a more sentence-like propositional structure. For example, the speaker decides on a suitable perspective from which to convey the content and an appropriate argument structure for the message (Levelt, 1989). By the end of the conceptualisation process the speaker has created a preverbal message that can be further processed for speech production.

Conceptualisation deficits in aphasia

While in unimpaired speakers these complex processes are carried out with ease, speakers with acquired language impairments (e.g., aphasia) can experience difficulties preparing their preverbal message. The majority of reports in this area have focused on symptoms at the microstructural level, such as the incorrect use of pronouns or impaired gender/number agreement (e.g., Marini, Andreetta, Tin, & Carlomagno, 2011). These deficits have mostly been attributed to the individuals' linguistic impairments (e.g., Andreetta, Cantagallo, & Marini, 2012; Armstrong, 2000; Armstrong, Ferguson, & Simmons-Mackie, 2013; Manning & Franklin, 2016; Marini et al., 2011).

However, the literature also reports macrostructural symptoms (e.g., a reduction in the amount of essential information produced; the occurrence of temporal sequencing errors) that may suggest underlying conceptualisation impairments in the discourse of some individuals with aphasia (Cairns, Marshall, Cairns, & Dipper, 2007; Dipper, Black, & Bryan, 2005; Hameister, Foxe, Hodges, Piguet, & Nickels, 2018; Hameister & Nickels, 2018). Since macrostructural planning takes place prior to speech production, traditional behavioural measures (e.g., spontaneous speech analysis) have limited ability to determine whether it is intact in speakers with aphasia (e.g., Dean & Black, 2005; Hameister & Nickels, 2018; Manning & Franklin, 2016; Marini et al., 2011).

Comparing the eye movement patterns of participants with and without aphasia performing the same task could potentially elucidate differences in early speech planning. Consequently, this paper aims to evaluate how far analysis of participants' eye movements during a discourse task can provide insights into early speech planning processes.

In addition, this paper aims to provide the reader with an overview of factors that have been found to influence eye movements in speech production and visual search tasks and use this literature to draw predictions regarding how these might affect gaze patterns during a complex picture description task. This aims to facilitate the reader's understanding of how eye movement analysis might support the diagnosis of possible difficulties with macrostructural planning.

Moving our eyes while viewing and describing a picture

The observation that an individual's eye movements represent their focus of attention on a visual stimulus, constitutes the foundation for the use of eye-tracking in the Human Sciences

(Henderson, 2017). Since speech planning loads heavily on attention (e.g., Levelt, 1989), eye movement analysis has the potential to provide valuable insights into general speech planning processes during a picture naming or description task (Ferreira, 2018).

Eye movements are usually described in terms of fixations and saccades. During a fixation the eye of the viewer stops on a specific entity for a short period of time to gather information about the fixated area. Saccades refer to the rapid movement from one fixation point to another, during which visual input is not acquired or processed (e.g., Griffin & Davison, 2011; Henderson & Hollingworth, 1998; Holsanova, 2008; Rayner, 1998).

Previous research has identified several factors that influence how a viewer moves his/her eyes over a visual scene. These depend either on the visuo-spatial features of the picture or the task, we address each in turn.

Influence of visuo-spatial features on scene viewing

Several visuo-spatial features of pictures, such as the animacy, saliency and spatial layout of visual information can influence the sequence and duration of gaze, with different effects depending on the viewer's goals (Henderson, 2017; Henderson & Hayes, 2018). For example, viewers are more likely to fixate objects in the centre of the visual stimulus than objects in marginal regions (e.g., Bindemann, 2010).

Additionally, visual *salience* has been widely argued to be an important influence on an individuals' eye movement pattern in simple visual inspection tasks (Henderson & Hayes, 2018; Wolfe & Horowitz, 2017). It has been reported, for example, that viewers are more likely to fixate regions with a greater visual contrast between discrete object entities and background imagery (Wolfe & Horowitz, 2017). However, visual salience is argued to play only a minor role when a complex task that requires more top-down processing is performed, for example, visual search for objects (e.g., Wolfe & Horowitz, 2017).

Even without a specific visual search task, Henderson and Hayes (2018, 2017) demonstrated that *meaning* rather than saliency guides the viewers' attention when inspecting real-world scenes (e.g., photograph of a kitchen). Regions of the visual stimulus that contain much meaningful information (e.g., faces, interactions) attract more attention than less meaningful areas (e.g., sky). Similarly, it is also widely acknowledged that animate entities, which typically carry much meaning, attract more attention than inanimate entities. Therefore, early fixations are mostly drawn to animate objects depicted in the visual scene (e.g., Antón-Méndez, 2017; Coco, Dale, & Keller, 2017; Griffin & Davison, 2011).

Ferreira (2018) analysed the influence of meaning density and visual salience on participants' gaze patterns when they described real-life scenes (e.g., photograph of a kitchen) in a way that enabled them to describe it later: areas with a high density of meaningful information were more likely to attract the viewers' attention than visually more salient areas without meaningful information (Ferreira, 2018).

Hence, the weight of evidence suggests that visual features that also hold conceptual information are likely to influence eye movement, particularly a viewer's early fixations on the target picture. Importantly, linguistic processes during speech planning have also been reported to influence and viewers' eye movement patterns and, at times, even override the influence of visuo-spatial features.

Influence of speech planning on scene viewing

While the analysis of eye movements in the field of Human Sciences has been predominantly used to investigate language comprehension (e.g., auditory sentence comprehension: Arantzeta et al., 2017; Hanne, Burchert, De Bleser, & Vasishth, 2015) and visual perception processes (e.g., Mele & Federici, 2012), an increasing number of eye-tracking studies have investigated speech planning and production (Cho & Thompson, 2010; Griffin & Davison, 2011; Huettig, Rommers, & Meyer, 2011; Meyer, van der Meulen, & Brooks, 2004; Thompson, Dickey, Cho, Lee, & Griffin, 2007).

Early studies using eye tracking in picture naming reported that participants' eye movements reflected speech planning for production (Meyer, Sleiderink, & Levelt, 1998).

Meyer et al. asked participants to name simple black and white line drawings of object pairs with high or low word frequency. (e.g., scooter and hat; Meyer et al., 1998). Participants first fixated and named the left-hand object before moving on to the right-hand object. Since word frequency of object names affected the viewing times, Meyer at al. suggested that participants only moved their eyes to the next object after speech planning for the currently fixated object was completed. This would seem to predict similar behaviour when participants describe a more complex picture. Moreover, if, for example, a participant omits information due to word retrieval difficulties, we might expect longer fixations on associated visual entities before the participant moves his/her eyes away without mentioning the entity name.

Griffin and Bock (2000) pioneered eye-tracking methods to investigate how people conceptualise and plan their speech. They asked two groups of participants to describe drawings of simple events using a single sentence (e.g., "*The mailman is chasing the dog*") either immediately upon seeing the picture (Group 1), or after a five second preparation phase (Group 2). Two further groups did not describe the picture, but were either instructed to detect the entity that was being acted on in the picture (Group 3) or to inspect the picture without a specific task (Group 4). It is the findings for Group 1 that are of importance here as these inform our understanding of the time course eye movements and speaking and their interaction.

When instructed to describe the picture immediately while viewing, participants showed an initial 'apprehension' phase of about 300ms during which they gathered a holistic information about scene. The authors argued that this phase enabled participants to conceptualise the depicted event. For a visually and semantically more complex picture we would hypothesise a longer apprehension phase.

Following this apprehension phase, the participants' eye movements were motivated by linguistic planning processes. Before speech onset, participants fixated on the region depicting the action and the entity performing the action. Griffin and Bock argued that this reflected early verb retrieval processes, which are necessary to conceptualise the sentence (e.g., determine the argument structure). After they started speaking, fixations to the entity that was being acted on were observed. Therefore, a participant's order of fixations to the main entities reflected the order in which they were mentioned in the sentence. This overlap of eye movements and speech production was taken to indicate sequential execution of the previously established speech plan (Griffin & Bock, 2000). Moreover, Griffin and Bock observed an 'eye-voice' span of approximately 900ms - the delay between the onset of the last fixation on an entity and then producing the entity's name in speech.

These pioneering studies investigating eye movements in speech production primarily used relatively simple visual stimuli (e.g., simple objects or events). However, the focus in this paper is on the more complex speech planning processes that are required for connected speech. We hope to tap into these processes using description of complex pictures. However, the idea to investigate the coupling of eye movements and verbal descriptions of a complex picture is not new: Chafe (1980) proposed that the investigation of a person's gaze pattern during a picture description could be an ideal way to gain further insights into the cognitive processes that underlie the ongoing conceptualisation process.

In 2008, Holsanova investigated descriptions of a colour scene depicting a number of objects and actions that could be named and were easily interpretable (e.g., digging, sowing, raking; Pettson and Findus: Ruckus in the Garden; Holsanova, 2008). Similar to Griffin and Bock (2000), Holsanova (2008) reported that fixations can both precede naming and occur in parallel with the production of an entity's name. However, Holsanova observed a substantially longer average eye-voice span of 2000ms (maximum reported: 5000ms) than Griffin and Bock's (2000). Moreover, she reported a number of distinct viewing patterns that she associated with different conceptual tasks.

A gaze pattern like that reported by Griffin and Bock (2000) in which participants first fixated an object and mentioned a shortly after, was associated with list like utterances (e.g., listing details, describing objects in detail; Holsanova, 2008). In contrast for the complex pictures, the most common pattern was 'N-to-1 mapping', characterised by multiple fixations on an area of interest both before, and during the participant talking about it (see Figure 1).

Holsanova proposed that this N-to-1 pattern was most commonly found when the participants aimed to summarise a section of the scene.

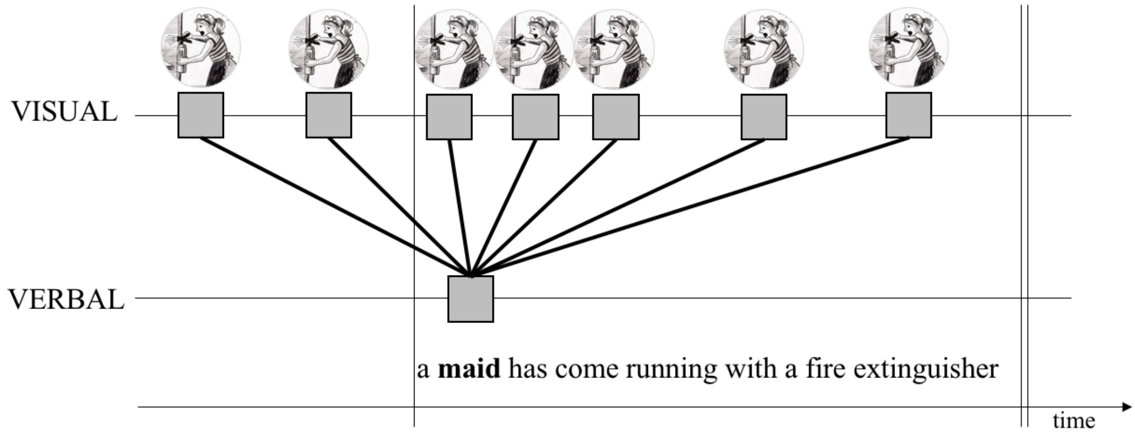


Figure 1: N-to-1 mapping pattern (adapted from Holsanova (2008), p. 104)

Holsanova's (2008), Griffin and Bock's (2000) and Meyer et al.'s (1998) studies illustrate how complex the relationship between gaze and picture description can be. Importantly, however, none of the literature to date has used complex pictures "whose meaning can be observed only through a synthesis of the relationship between and among actors and their actions" (Olness, 2006, p. 177) and that were likely to elicit a coherent narrative. For example, Holsanova's picture stimulus was more likely to elicit descriptive discourse that was focused on spatial and temporal details of the depicted (Holsanova, 2008; Longacre, 1983; Olness, 2006). Consequently, the conceptualisation requirements for this picture description are different from those of a story-like picture description and it remains to be determined how far the patterns of eye-movements will differ. Moreover, while Holsanova (2008) described in detail the possible viewing patterns that can arise during a complex picture description, she did not explicitly report how similar the viewing patterns and/ or the picture descriptions were across participants. Therefore, it remains unclear if even unimpaired participants show consistent eye movement patterns when inspecting and describing a complex scene. This is critical to establish before such a technique can be used to diagnose potential conceptualisation impairments.

In sum, while the literature gives us some ideas about possible links between eye movements and conceptualisation in speech production, it is still an under-investigated area. Nevertheless, it is one that has great potential to inform speech production theories as well as the diagnosis of possible speech and language impairments.

The current study

This exploratory study aimed to evaluate the feasibility and potential for applying eye-tracking measures in future language conceptualisation research. To achieve this aim, we first investigated the consistency of eye movements across unimpaired participants when planning to tell a story about a complex picture. Second, we compared these gaze patterns to those of a participant with aphasia. Finally, we aimed to gather data which can be used to generate hypotheses about possible differences from 'normal' eye movement patterns that might be associated with conceptualisation difficulties in people with aphasia.

Method

Participants

We recruited 10 language-unimpaired English native speakers (aged 18 - 25years) with normal uncorrected vison and no history of cognitive impairments as control participants. Data from four participants was excluded after testing due to technical difficulties (e.g., frequently lost signals). Hence, data from six unimpaired participants was available for analysis (mean age: 23 years, 2 male).

Additionally, we recruited two English-native speakers with aphasia and no history of uncorrected visual impairments such as hemianopia or neglect. Unfortunately, one participant experienced severe difficulties complying with the eye tracking testing situation (e.g., closed his eyes during speech production, had difficulties holding upper body in an upright position) and no reliable data could be obtained. Therefore, only one participant with aphasia, STR, was included in this study.

STR was 55 years old at the time of this study. He presented with chronic non-fluent aphasia and was three years post-onset. His spontaneous speech mainly consisted of well-formed sentences but was characterised by a very slow speech rate, speech sound errors and frequent word finding difficulties. STR showed deficits in naming both objects (Western Aphasia Battery (WAB): 40/60; Kertesz, 1982) and actions from pictures (Comprehensive Aphasia Test (CAT): action naming = 4/10; Swinburn, Porter, & Howard, 2005), with mostly phonological errors. His comprehension of simple spoken sentences and commands was well preserved (WAB: auditory verbal comprehension = 19.9/20) and he showed no difficulties understanding the task instructions during this study. Furthermore, STR's non-verbal skills on the CAT (Swinburn et al., 2005) showed no impairments: semantic memory (10/10), recognition memory (10/10), gesture use (12//12).

Apparatus

We recorded eye movements from the right eye using an EyeLink1000 remote eye-tracking system at a sampling rate of 500Hz (SR Research, 2010). The remote system was used to accommodate for any natural head movements that occur during speaking. However, a forehead rest was used to stabilise the participants' head movements and ensure that the participant did not move their head out of the trackable area. We recorded each participant's picture descriptions using a lapel microphone. The experimental stimulus was presented using Experiment Builder software (SR Research, 2011).

Stimuli

A black and white line drawing depicting a complex scene (i.e., 'Restaurant' scene) containing three animate entities and two connected main events (see Figure 2), was used to elicit a story-like picture description (Hameister, Nickels, et al., 2018).

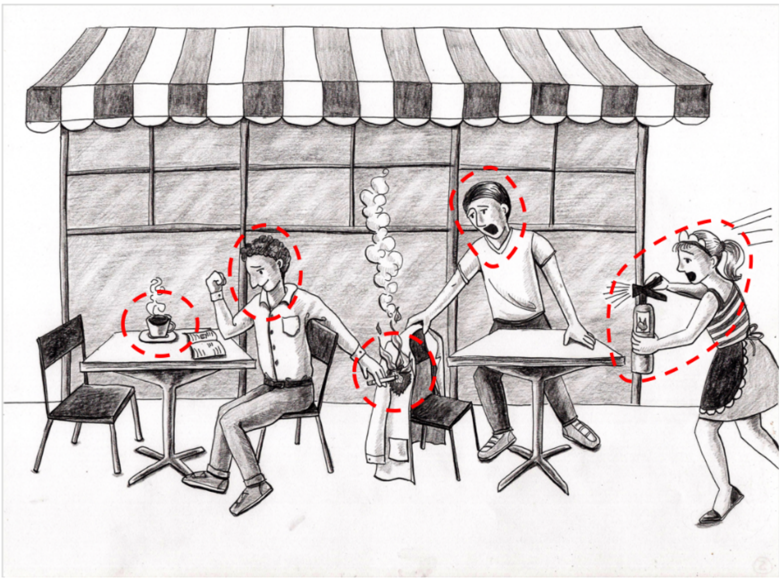


Figure 2: Stimulus picture for eye tracking task (the dotted lines represent the approximate position of the 5 pre-determined areas of interest). The AOIs will be later labelled as ‘Coffee’; ‘Smoker’; ‘Burn’; ‘Patron’ and ‘Waitress’ (from left to right)

Normative picture descriptions from 40 unimpaired participants were obtained for this picture in a previous study (Hameister, Nickels, et al., 2018). On the basis of these picture descriptions we identified eight central ideas (main concepts) that were mentioned by more than 70% of all participants and established a median concept order by determining the median position of each main concept in the description (see Table 1). Please note, that the main concepts ‘The man/ smoker is drinking a coffee’ and ‘The man/smoker is reading a book/magazine’ both hold the second position in the median main concept order, since across the participants they were used interchangeably in the second or third position of their picture description.

Table 1: Main concepts identified for the ‘Restaurant’ scene (Hameister, Nickels, et al., 2018)

Main concepts	mentioned by	Median order
The men are sitting in a café	95 %	1
The man/smoker is drinking a coffee	83 %	2
The man/smoker is reading a book/ magazine	93 %	2
The man/smoker is smoking a cigarette	85 %	3
The man/smoker does not notice anything	75 %	4
The man/smoker sets the coat of another patron on fire	100 %	5

The other patron notices the fire/ jumps up/ screams/*is reacting	70 %	6
The waitress comes with a fire extinguisher/ puts out the fire	100 %	7

Importantly for the study reported here, this normative data suggested that participants' picture descriptions were largely predictable. Consequently, we identified five Areas Of Interest (AOIs) around potentially important entities: 1) Coffee, 2) Smoker, 3) Burn, 4) Patron, 5) Waitress (see marked areas, Figure 1). The AOI around 'Waitress' also included the fire extinguisher. This decision was made, because both objects were in close visual proximity and were always mentioned together in the control sample picture descriptions (Hameister, Nickels, et al., 2018).

Procedure

The eye-tracking experiment was conducted in two phases: Inspection and Description (see Figure 3). Participants were instructed to carefully look at what was happening in the depicted scene for 10 seconds (Inspection phase). They were further told that a speaking symbol would appear to mark the end of the Inspection phase. After the symbol appeared, they were required to describe the scene by "telling a story with a beginning, a middle and an end" (Description phase). The task instructions were chosen to elicit narrative discourse that communicates semantic relations between depicted entities rather than a pure description of the scene (c.f., Olness, 2006). The experimenter demonstrated the length and structure of the required picture description outside of the eye tracker using the 'Cookie Theft' picture (Goodglass, Barresi, & Kaplan, 1983). The participants had as much time as they needed to complete their picture description and pressed the space button on the keyboard to indicate that they had finished their description, which stopped the recording of the audio and eye movements.

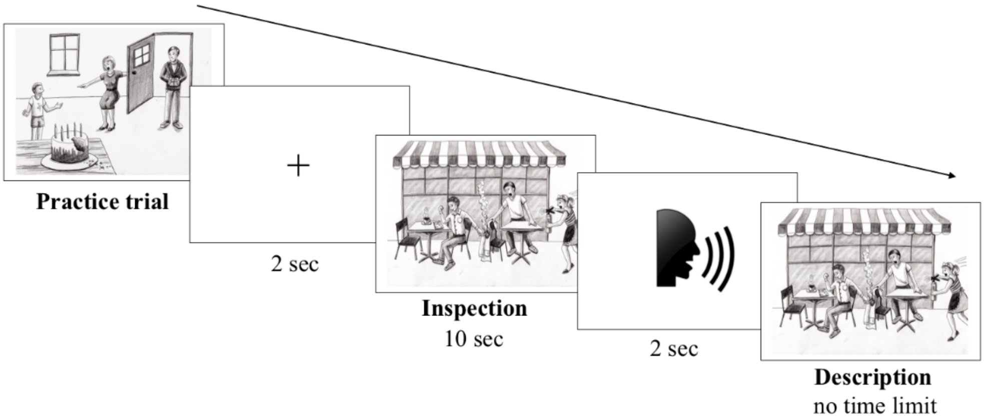


Figure 3: Timeline of the testing procedure during the eye tracking session

Prior to the start of the eye tracking experiment we conducted a standard 9-point calibration and validation. To familiarise themselves with the task and adjust to the unusual eye-tracking environment, participants completed two practice trials using two additional complex scenes, followed by a description of the experimental target picture.

We ensured that the participants' started the inspection and description phases from a central fixation by presenting a central fixation cross between trials, and central presentation of the speaking symbol before the description phase.

Analysis

Eye movement data was pre-processed and selected in SR Research's Data Viewer program (SR Research, 2017). We visually and statistically compared the time course of fixations to AOIs across all participants to investigate differences in order of fixations that might represent differences in conceptualisation processes. We also analysed the content of the participants' picture descriptions and compared the order in which entities were mentioned to the order in which they were fixated. Below we explain the steps of the analysis in more detail.

Analysis of the Inspection phase

In order to identify and compare when each participant fixated the individual AOIs of the 'Restaurant' scene, we conducted a time course binning analysis (SR Research, 2017). First, we analysed the participants' fixations during the entire Inspection phase (10 seconds) to gain insights into the preparation of their picture description.

A series of short time bins were set across this pre-determined time period. A number of studies have analysed the time course of fixations to investigate time-sensitive processes using time course binning analysis (e.g., novel word learning; Weighall, Henderson, Barr, Cairney, & Gaskell, 2017) and reported a variety of bin durations (e.g., Griffin & Davison, 2011). Consistent with several studies, we implemented 50ms bin durations, (e.g., Borovsky, Sweeney, Elman, & Fernald, 2014; Ito, Pickering, & Corley, 2018; Weighall et al., 2017). This resulted in a total of 200 bins set for the entire Inspection phase.

For each time bin the participants' fixations to each of the AOIs were tallied and the total fixation duration summed in a time-course binning report. For unimpaired participants we created a collapsed time-course binning report that provided averaged fixation data for each trial across all participants (SR Research, 2017). This was performed to evaluate the likelihood of fixation on a certain AOI of the 'Restaurant' scene at any given time point. We also created individual reports giving the time course of fixations on the AOIs for each unimpaired participant and STR.

We then visualised the data obtained from the time-course binning analysis. Visualisation of eye-tracking data is a common starting point for more detailed data analysis (Kurzhals et al., 2015). Apart from providing a general overview and understanding of the data, an appropriate visualisation can also help to generate hypotheses about underlying cognitive processes that led to the observed gaze patterns (Andrienko, Andrienko, Burch, & Weiskopf, 2012).

In this study we created scarf plots for each of the five AOIs in the 'Restaurant' scene. In a scarf plot, every event that occurs over a pre-defined period of time (i.e., Inspection phase) is coded with a specific colour. In this study, each fixation to an AOI marks a significant event and plots for each of the five AOIs in the 'Restaurant' scene were created. A fixation to an AOI was displayed in the scarf plot when a participant spent greater than 50% of the 50ms time bin fixating that specific AOI. Periods of time during which a participant fixated an AOI were marked with one colour and periods of time without fixation to that AOI were marked in a different colour.

We then visually compared the temporal overlap of fixations on each AOI across participants and statistically compared the onset times of first fixations and fixation durations to each AOI made by STR and unimpaired participants using Crawford's single case statistics (Singlims; Crawford, Garthwaite, Azzalini, Howell, & Laws, 2006).

Analysis of the Description phase

Once again, we performed time-course binning analysis to investigate the participants' fixations to AOIs during their picture descriptions. Since each participant's picture description differed in length, to make results more comparable, we restricted analysis for unimpaired participants to the first 10 seconds of the description.

As STR showed considerably slower speech production than unimpaired participants, we analysed the first 30 seconds of his description. This ensured that the amount of content he produced in his picture description and therefore the sequence of eye movements associated with this content, was more comparable to the unimpaired participants.

Yet again, we used 50ms time bins across the pre-defined time periods of the Description phase and tallied the fixations to each AOI and the total fixation duration to AOIs in a time course binning report. This phase resulted in data from 200 time bins for unimpaired participants and 600 time bins for STR. The participants' fixations to each AOI were subsequently visualised in scarf plots and the observed eye movement patterns visually compared.

We also transcribed the participants' picture descriptions orthographically. We then identified the main concepts the participants produced and the order in which they were mentioned. Additionally, we aligned the words of the first 10/30 seconds of the picture descriptions of unimpaired participants and STR, respectively, with their fixations to relevant

AOIs in the scarf plots. This enabled us to calculate the eye-voice span (Griffin & Bock, 2000) - the time difference between the onset of the last fixation to an AOI and the onset of the word that describes the entity in that area. We statistically compared the average eye-voice spans of the unimpaired participants and the participant with aphasia (STR) using Crawford's single case statistic tool Singlims (Crawford et al., 2006).

Results and Discussion

Analysis of Inspection phase: Unimpaired participants

For unimpaired participants, we observed early fixations on the AOI 'Smoker' at 250 ms after the picture onset (see Figure 4, panels A and B). Furthermore, they also showed early fixations to the 'Patron' and the main event (here labelled 'Burn') within the first 1200 ms. Neither the AOI 'Smoker' nor the AOI 'Patron' were in close proximity to the (prior) location of the fixation cross. Therefore, it is unlikely that the participant' first fixation was just the entity that replaced the fixation cross. Instead, we suggest that the pattern is consistent with participants showing early fixations to the areas that were most salient or showed a high meaning density (e.g., animacy, strong visual contrast; Griffin & Davison, 2011; Henderson & Hayes, 2017).

Following this first apprehension phase, we observed another period of around 3700ms (between 1300ms and 5000ms) in which the unimpaired participants did not show a clear preference for any AOI (see Figure 4, Panel A, grey area). During this time, the participants viewing patterns suggest inspection of the entire picture. We propose that this 3700ms period may compare more closely to the apprehension phase reported by Griffin and Bock (2000) than the 300ms phase we also observed in the beginning of the Inspection phase. Griffin and Bock (2000) suggest that the inspection of the entire scene observed in this time span indicates a holistic conceptualisation process, during which the viewers establish relationships between the individual entities and determine an appropriate starting point for their picture description.

From 5000ms onwards, four of the AOIs can be clearly distinguished. Participants started fixating the AOI around the 'Smoker' moving on to the 'Burn', the 'Patron' and the

'Waitress'. The order in which these areas were fixated matched the order in which these entities were mentioned as main concepts in the picture description later and seem to suggest that the participants' eye movements were driven by the linguistic conceptualisation process (e.g., ordering inforamtion, retreive words; Griffin & Bock, 2000).

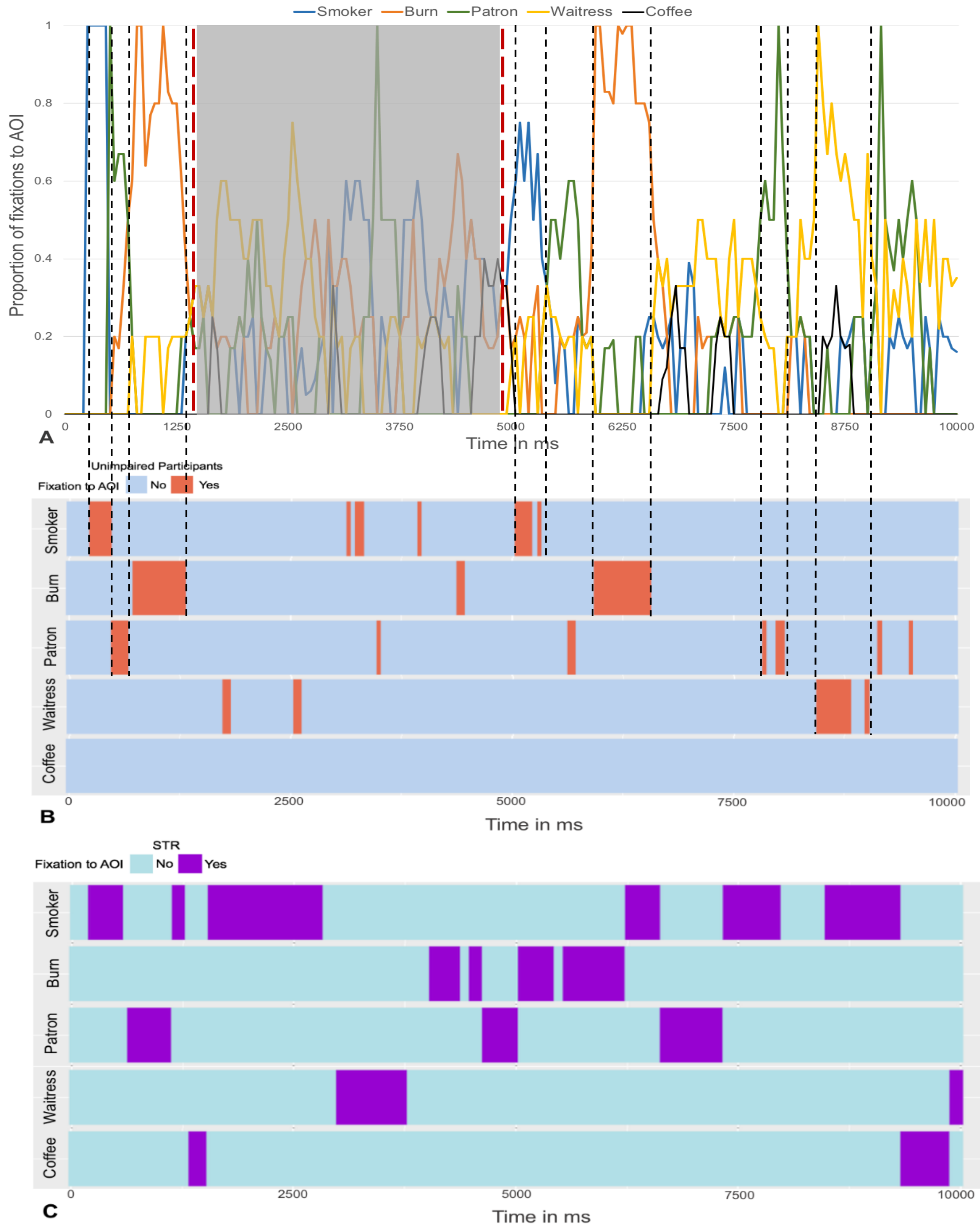


Figure 4: Panel A: Changes in mean proportion of fixations unimpaired participants made on any of the five predefined AOIs (here labelled; 'Smoker'; 'Burn'; 'Patron'; 'Waitress'; 'Coffee') across successive 50ms intervals over the entire Inspection phase. The grey area in marks the time span in which the viewers did not clearly distinguish between the areas. The arrows indicate the distinctive peaks of individual AOIs. Yes = AOI fixated on average for more than > 60% of the 50ms bin. **Panel B**: Scarf plot of unimpaired participants' fixations to AOIs across successive 50ms intervals over the entire Inspection phase. **Panel C** = Participant with aphasia's (STR) fixations to AOIs across successive 50ms intervals over the entire Inspection phase. Yes = AOI fixated on average for more than > 60% of the 50ms bin.

On average, the AOI around ‘Coffee’ was never fixated for more than 60% of a 50ms time bin during the Inspection phase and hence does not appear in the scarf plot (see Figure 4, Panel B). The majority of participants in an earlier study (Hameister, Nickels, et al., 2018), mentioned that ‘the man drinks coffee’ in their picture description, therefore the region around the coffee cup were chosen as an AOI in the beginning of the study. Indeed, every unimpaired participant fixated the ‘Coffee’ AOI for at least a short amount of time during the Inspection phase. However, these fixations were very short (between 50 and 450ms) and showed little temporal agreement across participants (see Figure 5).

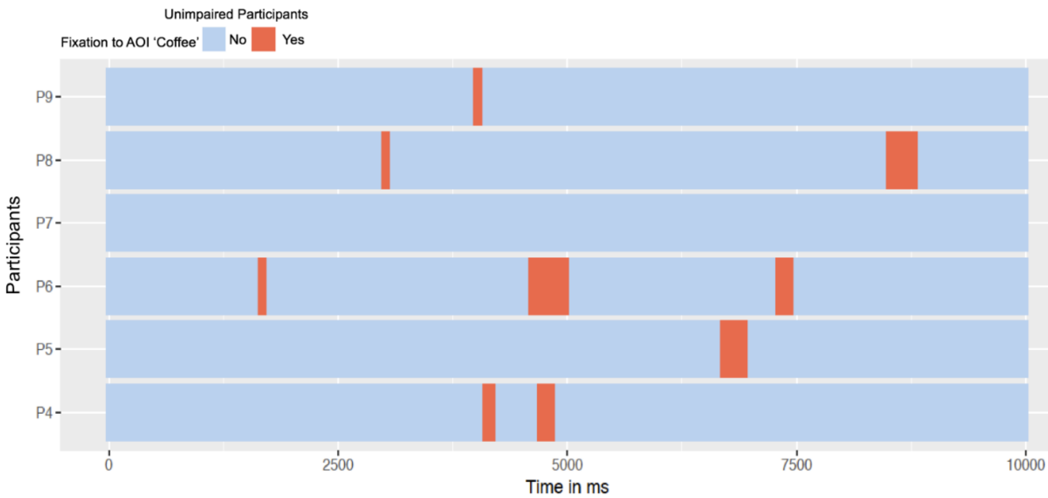


Figure 1: Unimpaired participants’ fixations on the AOI ‘Coffee’ across successive 50ms intervals over the entire Inspection phase

It is possible that the ‘Coffee’ AOI may not have been sufficiently visually salient or meaningful in the context of the event to attract attention for longer (Henderson & Hayes, 2018, 2017). Consequently, participants may have either processed the information provided by this area very fast or gathered more visual information parafoveally when fixating a different area (e.g., “Smoker”; Henderson & Hollingworth, 1998; Holsanova, 2008).

Analysis of Inspection phase: STR

As we were only able to obtain eye movement data from one participant with aphasia (STR), we extracted categorical data that indicated whether STR was fixating on one of the AOIs for over 60% of any given 50ms time bin or not. Panel C of Figure 4 displays STR's fixation on each AOI during the entire Inspection phase (fixations to AOI marked in purple).

Initially, STR showed a similar pattern to the unimpaired participants, with very early fixations to the 'Smoker' at 208ms and the 'Patron' at 650ms after the picture onset. As with the unimpaired participants, we think it possible that STR's attention was first drawn to areas with strong visual saliency or a high density in meaning (e.g., animacy; Henderson & Hayes, 2018).

Moreover, while unimpaired participants spent only a few milliseconds fixating the 'Smoker' in the beginning of the Inspection phase, STR continued to fixate the 'Smoker' area until about 2750ms into this phase. This could suggest, that, in anticipation of the picture description, STR attempted word retrieval during his first fixation to this entity. However, it is also possible that unimpaired participants also started word retrieval with the first fixation but that STR was much slower in retrieving the word than unimpaired participants.

Interestingly, STR's first fixation on the AOI depicting the critical main event ('burning jacket') occurred significantly later than that of the unimpaired participants (STR = 4064ms; $mean_{Unimpaired}$: 1075ms ± 529.74; t=5.224, *p*=.002; Singlims). Figure 6 further illustrates this difference showing fixations to 'Burn' for each unimpaired participant and STR.

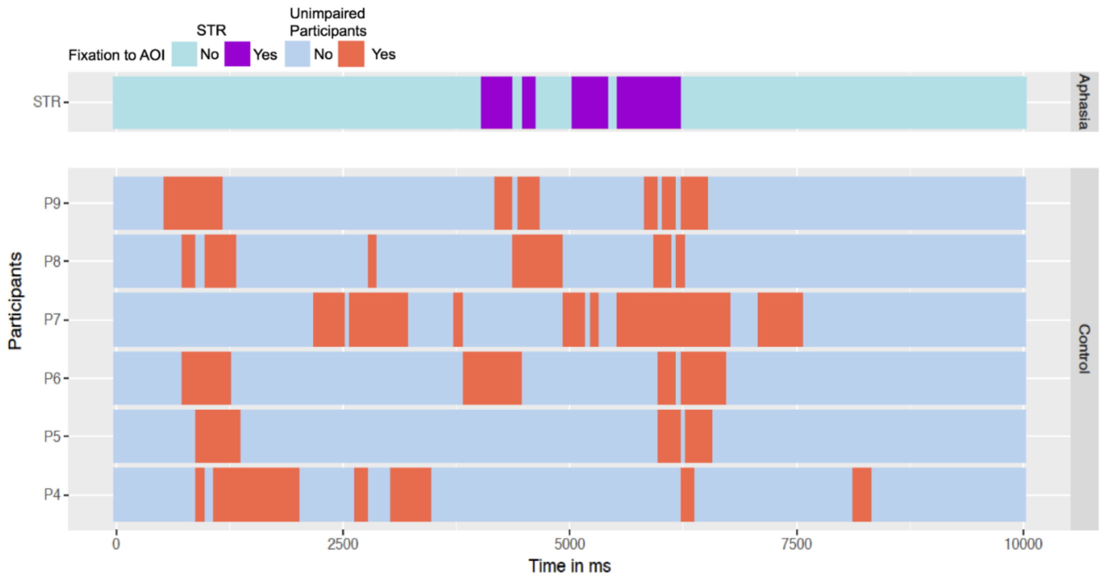


Figure 6: Participants' fixations to AOI around the critical main event 'Burn' across successive 50ms intervals over the entire Inspection phase

As with our unimpaired participants, Griffin and Bock (2000) observed early fixations to the action in their simple event pictures. The authors suggested that this was necessary for participants to determine the most appropriate argument structure for the sentence they were about to say. Similarly, participants in our study needed to decode the central main event in order to be able to conceptualise the rest of the depicted story (e.g., *Who did it?; Whose jacket is it?; How is the problem resolved?*).

Our data is consistent with the unimpaired participants in our sample identifying the critical main event of the picture very quickly (mostly within the first 1000ms). In contrast, STR's fixations suggest that he needed significantly more time to identify the main event of the 'Restaurant' scene. This could indicate that his entire conceptualisation process was slowed.

The successive fixations to AOIs in the last 5 seconds of the Inspection phase for unimpaired participants seemed to suggest that they had completed their planning of the picture description within the 10 seconds provided. In contrast, STR's long fixations to the 'Burn' and 'Smoker' AOIs suggest that he was slower to identify the conceptual links between entities/ events depicted in these areas and to identify the main event. STR's significantly longer fixation on the 'Smoker' AOI (STR = 3390ms; $mean_{Unimpaired}$=1832 (± 331.45); t=3.39, *p*=.010; Singlims, Crawford et al., 2006) and shorter fixation times on the 'Waitress' AOI (STR=770ms;

$mean_{Unimpaired}$=2154 (± 331.45); t=-2.25, p=.037; Singlims) seem to further support this idea. We suggest that STR appeared to have needed more than 10 seconds to appropriately prepare his picture description. This might also be true for other participants with aphasia. In future experiments with people with aphasia, we would therefore recommend the use of a longer or self-paced Inspection phase.

Analysis of the Description phase

In this analysis we compared the number and order of main concepts produced by unimpaired participants and STR, and compared their fixation patterns during their picture description. Due to technical difficulties, eye movement data of one unimpaired participant (P9) was not available for the description phase, leaving data from only five unimpaired participants for this analysis. We present below the results for the number and order of main concepts produced, as well as the observed gaze pattern, separately for unimpaired participants and STR.

Number and order of main concepts produced: unimpaired participants

Unimpaired participants produced on average 6.3 (±1.51) main concepts. This resembles previous findings of Hameister, Nickels et al. (2018) who identified an average of 7 (±1.03) main concepts in the 'Restaurant' description of 40 unimpaired participants.

The order in which the unimpaired participants produced their main concepts also followed the concept order previously reported for the 'Restaurant' scene (Hameister, Nickels, et al., 2018) (see Table 2, below). Only one unimpaired participant (P9) mentioned two of the main concepts in the reverse order to the remaining participants with "*the waitress is coming to help*" in the penultimate position and the main concept about "*the patron is upset*" in the last position. This position change did not affect the overall comprehensibility of the description, nor constituted an error in the temporal ordering of events. We consider it possible that this participant might have adhered less to the given task instructions and produced a more descriptive picture description rather than linking the individual ideas into a coherent story.

Minor deviations from the median main concept order were also observed in the group of unimpaired participants reported by Hameister, Nickels et al. (2018). As noted above, the order in which the unimpaired participants mentioned the main entities/event (‘Smoker’, ‘Burn’, ‘Patron’, ‘Waitress’) in their picture descriptions, matches with the order in which they fixated on these AOIs during the last 5 seconds of their inspection Phase (see Figure 4A). This suggests that the participants used this last five seconds to determine the coarse structure of their picture descriptions and completed their planning within the given Inspection time.

Number and order of main concepts produced: STR

STR produced only 4 of the 8 possible main concepts. However, this does not mark a significant difference compared to the average of unimpaired participants in this study (t= -1.42, *p*=0.10). While each unimpaired participant explicitly mentioned the main concept “*The man is smoking a cigarette”*, STR did not (see Table 2). He did mention, however, that the man held the cigarette *“behind him”* and thereby communicated that there was a cigarette, and that this had something to do with the depicted fire. We consider it possible that STR was not able to retrieve the word ‘smoking’.

Table 2: Example of the entire “Restaurant” scene descriptions of one unimpaired participant (JBA) and the participant with aphasia (STR).

Transcript unimpaired participant P6	**Transcript participant with aphasia STR**
Two different people havening ehm a nice coffee at the cafe and one of them is being careless *while smoking* and *it's bu- the cigarette is burning a hole in the guy's jacket*. *The maid is running over to assist*. Hopefully the man will realise what he has done and apologise and maybe offer to buy a new jacket.	At a outdoor c-c-... restaurant *a ... maid has come running with the extinguisher* because the boys jacket is on fire. the other *man is sitting there with his coffee* *reading a book* with a cigarette behind him which has made his ehm … the jacket … eh *set it on fire*. And now the maid comes and … puts out the fire.

Note: Italic and underlined = main concepts identified in the picture description. P6 = 4 main concepts; STR = 4 main concepts

Additionally, STR showed a very different main concept order from the unimpaired participants by starting his description with “*the waitress is coming to help*”. Nevertheless, while this main concept order is unusual, and was not observed in any of the unimpaired participants, it does not constitute a temporal sequencing error. STR's picture description reveals that he did identify the 'Smoker' as the causer of the depicted incident (see Table 2). After his unusual start, STR continued the picture description in a similar way to unimpaired participants and mentioned the same number of main concepts. He later also repeats the main concept about 'Waitress' at the end of his description, which shows that he was aware how this main concept links into the time course of the depicted event. Consequently, STR seems able to conceptualise the depicted events. Nevertheless, his conceptualisation process may be substantially slowed down compared to unimpaired speakers.

Interestingly, during the Inspection phase, STR fixated on the 'Waitress' AOI last, before he started his picture description (see Figure 4C). Since it is reported that people with aphasia may have difficulties switching their visual attention (e.g., Murray, 2012), we considered the possibility that STR might not have been able to redirect his attention fast enough. Therefore, he may have started his description with the entity that last attracted his attention, which in turn, led to the observed temporal sequencing error.

Gaze patterns during description: unimpaired participants

To illustrate the unimpaired participants' eye movements during the description phase, we display the fixation pattern of one participant (P6) aligned with the first 10 seconds of her picture description (in Figure 7A, below). P6's fixations on the relevant AOI preceded her speech production of that element by 400 to 2,000ms, giving a mean eye-voice span of around 950ms ($mean_{eye\text{-}voice\ span}$ = 947.75 (± 742.61). On average, the five unimpaired participants whose eye-tracking data for the description phase was available showed an eye-voice span of 1064ms (± 531.95) (see Appendix A).

These findings replicate the average eye-voice span (900ms) reported by Griffin and Bock's (2000) for simple picture descriptions without a preparation phase. Griffin and Bock (2000) suggested that this provides evidence for a successive selection and phonological encoding of the target nouns during the execution of participants' previously established speech plans. Similar assumptions can be made for the unimpaired participants in this study. The similarity between the eye-voice span found here and that reported by Griffin and Bock (2000), also suggests that unimpaired participants were able to use the Inspection phase of this study to structure their descriptions and possibly break them down into multiple simple events that make up the whole story during.

In line with reports of Griffin and Bock (2000), all unimpaired participants also fixated on the AOI's while they were talking about associated content. For example, for P6 this pattern became particularly clear when, around 5,000ms into her picture description, she started to talk about the incident of the 'burning jacket' and keeps fixating on the corresponding AOI 'Burn' (see Figure 7A).

Gaze patterns during description: STR

STR showed a significantly longer eye-voice span than unimpaired participants (see Figure 7B). His eye-voice span varied between 1,200 - 4,800ms (mean = 3,426.33 (± 2008,76); t= 4.05, *p*=0.08), which resembles the findings of Holsanova (2008). Holsanova (2008) found an average eye-voice span of around 2000ms for unimpaired speakers who described a complex scene without any preparation time. She proposed that prolonged eye-voice spans reflect more complex cognitive processes pre-verbalisation, including broader conceptual processes (e.g., determining if information is important for the picture description; Holsanova, 2008).

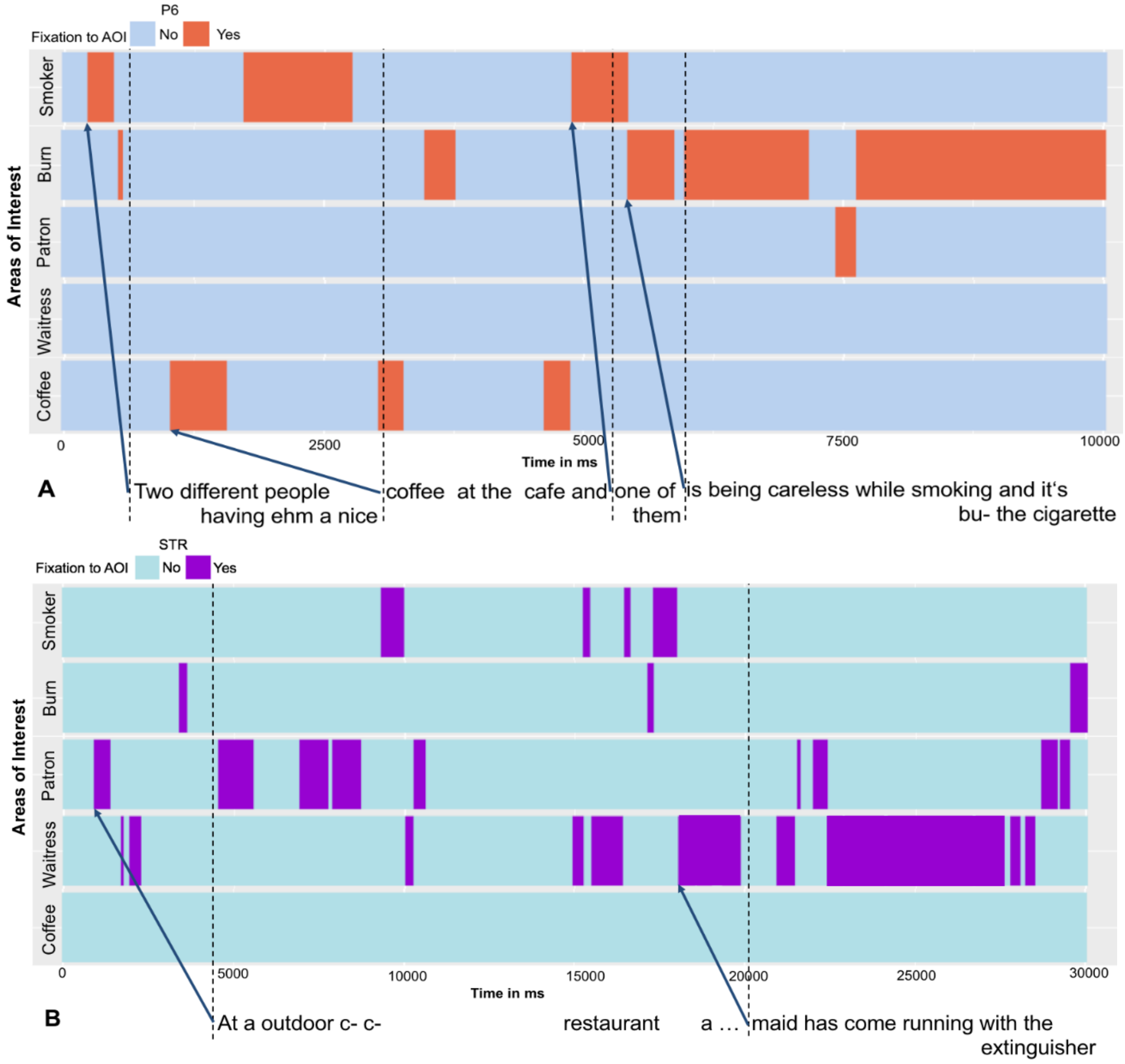


Figure 7: Panel A: P6's fixations to AOIs across successive 50ms intervals over the first 10 seconds of the description phase aligned with the first 10 seconds of her picture description. Panel **B:** STR's fixations to AOIs across successive 50ms intervals over the first 30 seconds of his description phase aligned with the first 30 seconds of his picture description.

Note: The vertical black lines represent the speech onset of the word written behind the line (P6: "two"; "coffee"; "one"; "is" STR: "at"; "maid"). The arrows point to the onset of the last fixation to the associated AOI (values used to calculate eye-voice span). The AOI 'Patron' was associated with the STR's phrase "at an outdoor restaurant", since the shop canopy, that identifies the restaurant as being "outdoor", can be perceived by parafoveal viewing while fixating the AOI 'Patron'

The difference we observed between the eye-voice spans of STR and the unimpaired participants support our earlier hypothesis that only the unimpaired participants managed to appropriately prepare most of the picture description within the 10 second Inspection phase. Since STR's description preparation was not completed, he needed more time for conceptualisation during the description phase, as demonstrated by longer pauses in production, longer fixation times on related AOIs, and a longer eye-voice span (Holsanova, 2008; Levelt, 1989; Meyer et al., 1998). Importantly, however, in STR's case the extended eye-voice span might also reflect slower word retrieval as the result of his expressive difficulties.

Similar to the unimpaired participants in this study, STR also fixated on the AOI's while he was taking about the entity depicted in the area. For example, he demonstrated prolonged fixations to the 'Waitress' AOI while talking about this event (see Figure 7B, end of the description).

STR's viewing pattern between 15,000 and 28,000ms clearly shows the pattern described as 'N-to-1 mapping' described by Holsanova (2008; see Figure 1). STR fixated several times on the AOI 'Waitress' before he mentioned this entity ('maid'), and keeps returning to this area during the rest of his statement. According to Holsanova (2008), this viewing pattern suggests a prolonged conceptualisation process in which visual information is a) interpreted and b) linguistically encoded.

The fact that this 'N-to-1 mapping' pattern is not apparent in unimpaired participants, supports our suggestion that most of their conceptualisation and utterance planning has already been completed during the Inspection phase. Consequently, their eyes predominantly move in parallel with their speech production during their picture description (Holsanova, 2008).

Summary and Conclusion

This study aimed to evaluate the feasibility of, and potential for, the use of eye tracking in future language conceptualisation research. It did so by investigating the consistency of eye movements across unimpaired participants and comparing their eye movement patterns to those of a participant with aphasia. The results demonstrate the close relationship between eye movements and conceptualisation for speech production in a complex picture description.

We observed substantial agreement in the eye movement patterns of unimpaired participants during their speech planning and production, suggesting that similar conceptualisation processes had taken place across participants. This finding further indicates that it is possible to compare the eye movement patterns of participants with acquired language impairments, or other clinical populations, to the “normal” viewing pattern. This is the necessary foundation for the use of eye tracking in further clinical research.

Additionally, we found that the order in which unimpaired participants fixated the AOIs in the final portion of the Inspection phase predicted the order in which they mentioned them in their picture descriptions. In contrast, the fixation pattern of the participant with aphasia in this study (STR) showed clear differences (e.g., longer fixation times, delayed fixation to critical areas, different order of fixations, longer eye-voice span).

We consider it possible that the differences observed in STR’s eye movement pattern may be explained by an overall slowing of conceptualisation. Therefore, he was not able to use the Inspection phase as efficiently as the unimpaired participants to prepare his description. This is reflected in an eye-movement pattern (i.e., N-to-1 pattern), which indicated greater involvement of speech planning processes during STR’s description than was observed in unimpaired participants.

In line with reported symptoms of possible conceptualisation impairments, STR showed an atypical order of main concepts in his picture description, by starting his description with a main concept (‘Waitress’) that was mentioned at the end of the description by all unimpaired participants (e.g., Cairns et al., 2007; Carragher, Sage, & Conroy, 2015; Hameister & Nickels, 2018; Manning & Franklin, 2016). Interestingly, STR mentioned the ‘Waitress’ again at the end of his description. However, apart from conceptualisation difficulties, this also might be the result of a slowed conceptualisation process: STR may not have been able to conceptualise how the ‘Waitress’ links into the depicted story until later in his description. Additionally, during the Inspection phase, STR last fixated on the AOI ‘Waitress’ before he started his description. We consider it possible that his slowed conceptualisation in combination with a reduced ability to shift visual attention quickly across the scene (e.g., Murray, 2012) may have caused STR to start with the entity that was last in the focus of his attention (i.e., ‘Waitress’).

Further assessments of STR's attention skills would be necessary to confirm this hypothesis. In future research, we consider it important to complement the analysis of eye movements with further neuropsychological (e.g., attention, executive functions) and language testing (e.g., word retrieval, sentence comprehension), to be able to better interpret the observed fixation pattern and gain a clear idea of the underlying nature of a participants' language impairment.

We are aware that this study can only be considered exploratory, comprising a single participant with aphasia and a modest sample of unimpaired participants. Nevertheless, our eye-movement analyses were sensitive to differences between unimpaired participants and this one participant with aphasia, suggesting that this could be a promising technique for future case series involving individuals with language production difficulties.

In conclusion, our results suggest that eye-tracking can be used as an innovative method to further investigate conceptualisation processes in aphasia and gain information about possible deficits.

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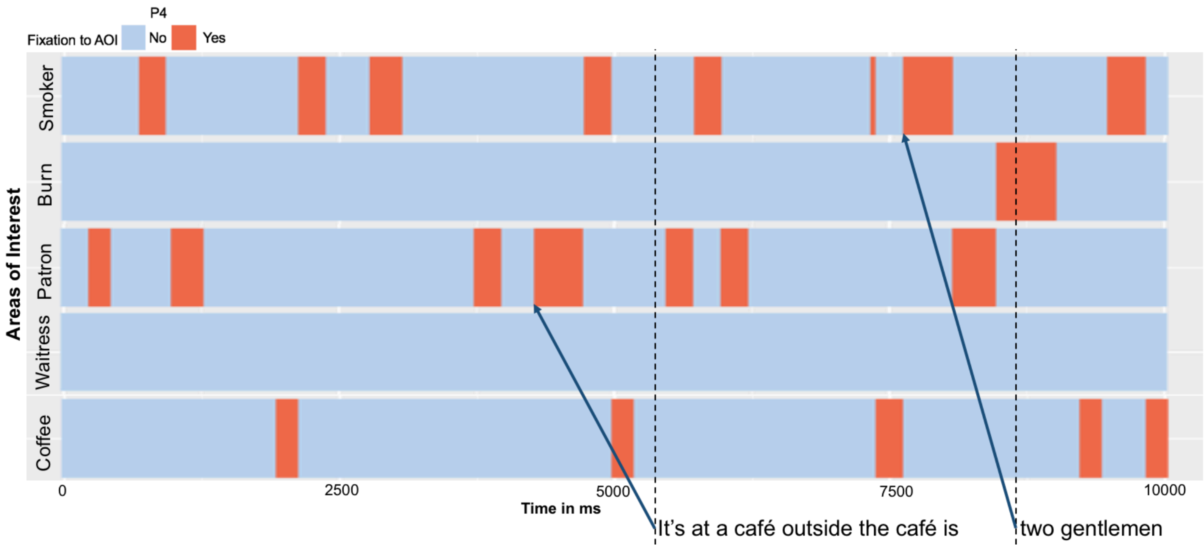
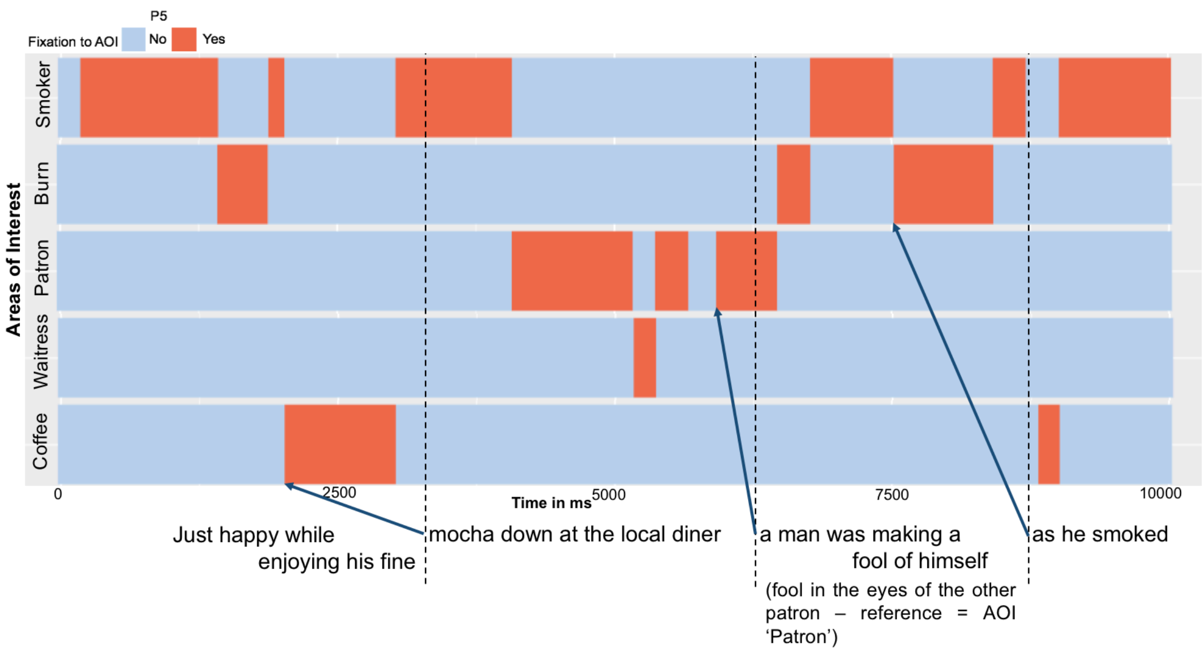
Appendices

Appendix A: Unimpaired participants' fixations to AOIs across successive 50ms intervals over the first 10 seconds of the description phase aligned with the first 10 seconds of their picture descriptions

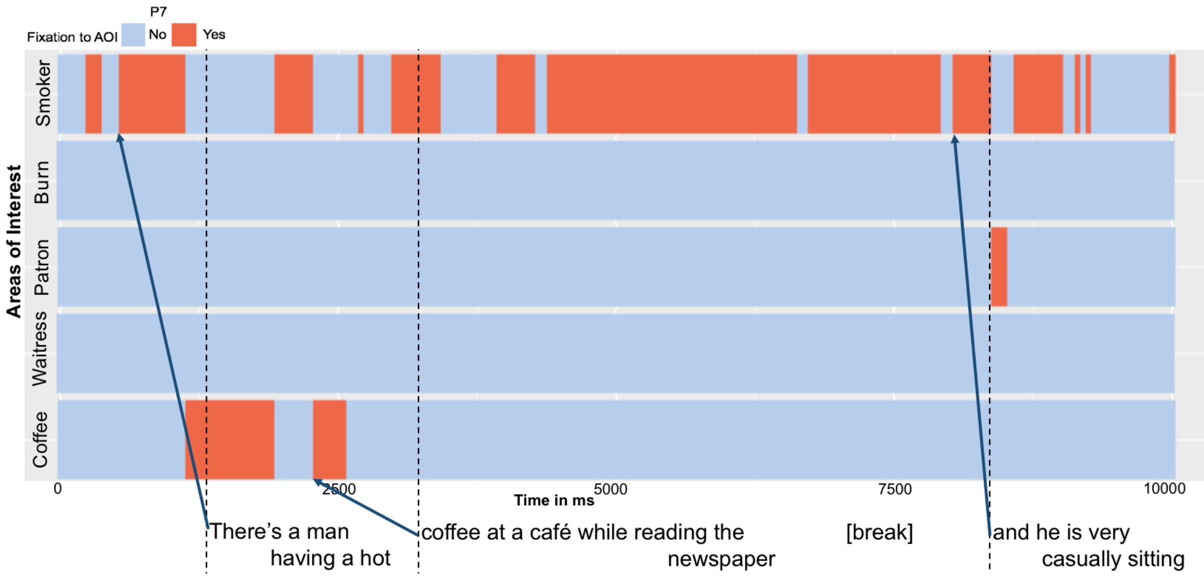
P4:



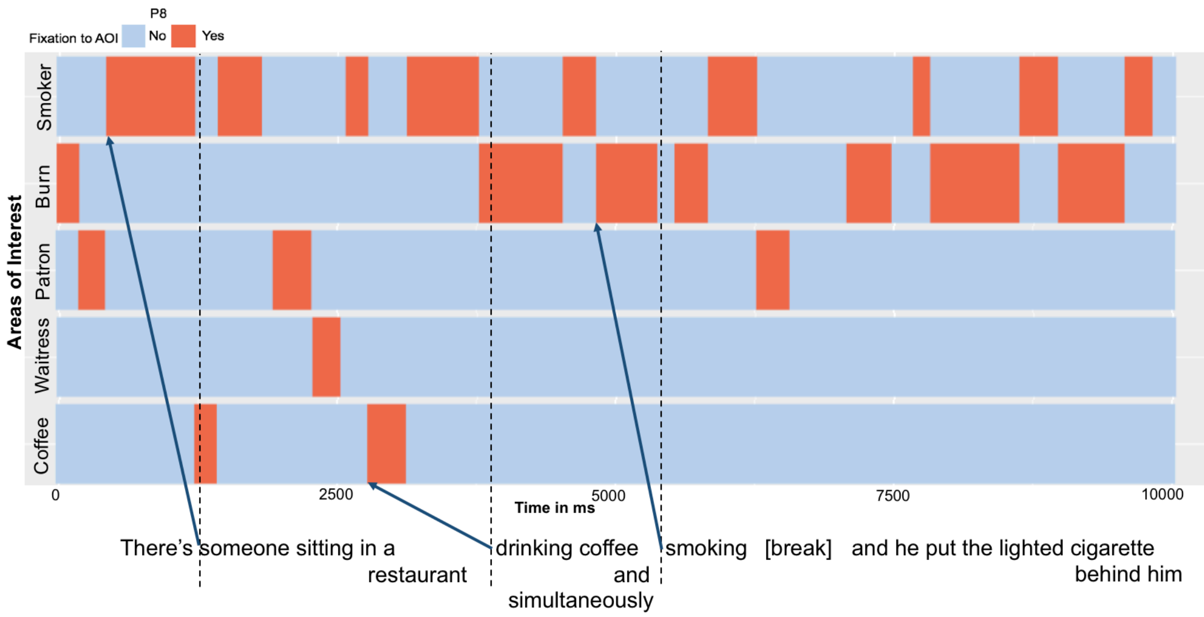
P5:



P7:


P7
Fixation to AOI
No
Yes
Areas of Interest
Smoker
Burn
Patron
Waitress
Coffee
0
2500
5000
7500
10000
Time in ms
There's a man having a hot
coffee at a café while reading the newspaper
[break]
and he is very casually sitting

P8:


P8
Fixation to AOI
No
Yes
Areas of Interest
Smoker
Burn
Patron
Waitress
Coffee
0
2500
5000
7500
10000
Time in ms
There's someone sitting in a restaurant
drinking coffee and simultaneously
smoking
[break]
and he put the lighted cigarette behind him

CHAPTER 6

General Discussion

Motivated by an interest in investigating whether potential conceptualisation impairments highlighted in the 'Thinking for Speaking' literature of people with neurological language impairments, also occur at the macrostructural level of discourse, this thesis had two overarching aims: First, the development and evaluation of a practical and clinically applicable method for identifying deficits in the macrostructural organisation of the discourse of people with neurological language impairments (i.e., **Chapter 2**: stroke-induced aphasia and **Chapter 3**: primary progressive aphasia). Second, to provide new insights into the contribution of specific linguistic impairments (i.e. word retrieval) and broader cognitive conceptualisation processes to observed macrostructural symptoms. This was achieved using innovative approaches like the 'Taboo-paradigm' (**Chapter 4**) and the analysis of eye movement during a picture description task (**Chapter 5**).

Main experimental findings

In **Chapter 2**, I used a modified main concept analysis approach (Nicholas & Brookshire, 1993, 1995) to analyse the amount, quality and order of essential information as well as the amount and quality of non-essential information produced in the 'Cat Rescue' picture descriptions (Nicholas & Brookshire, 1993) of 50 unimpaired participants and 50 participants with stroke-induced aphasia. In **Chapter 3**, I performed the same analysis on the "Cookie Theft" picture descriptions (Goodglass, Barresi, & Kaplan, 1983) of 20 unimpaired participants and 60 participants with primary progressive aphasia (PPA) of all three variants (20 non-fluent (nfv), 20 semantic (sv) and 20 logopenic (lv); see, Gorno-Tempini et al., 2011).

These analyses investigated the occurrence of three main symptoms that had been previously documented in single case studies:

4. *Reduced informativeness represented by little essential information* (e.g., Andreetta, Cantagallo, & Marini, 2012; Cairns, Marshall, Cairns, & Dipper, 2007; Christiansen, 1995; Huber, 1990; Marshall, Pring, & Chiat, 1993; Nicholas & Brookshire, 1995; Ulatowska, Freedman-Stern, Doyel, Macaluso-Haynes, & North, 1983).

5. *An unusually large amount of non-essential or detailed information* (e.g., Cairns et al., 2007; Dean & Black, 2005; Marshall, 2009; Marshall et al., 1993)
6. *An unusual order of information* (e.g., Cairns et al., 2007; Carragher, Sage, & Conroy, 2015; Manning & Franklin, 2016)

Chapters 2 and 3 showed for the first time that these macrostructural symptoms occur far more often in participants with neurological language impairments than the literature previously suggested (e.g., Armstrong, 2000; Ash & Grossman, 2015; Linnik, Bastiaanse, & Höhle, 2016; Marini, Andreetta, Tin, & Carlomagno, 2011; Ulatowska et al., 1983). Overall, 66% of participants with stroke-induced aphasia and 51.7% of participants with PPA showed at least one symptom. Furthermore, these symptoms were observed in all possible combinations, resulting in seven distinct symptom patterns (see Table 1). However, only one participant with stroke-induced aphasia showed all three macrostructural symptoms. At a sentence level a reduction in essential information; large number of non-essential information and an unusual sequencing of information had been previously reported for Ron, a man with non-fluent/agrammatic aphasia (Cairns et al., 2007). However, in contrast to Ron, the participant identified in Chapter 2 (AphasiaBank ID: ACWT11a) was diagnosed with a fluent Wernicke's type aphasia. This could suggest that different impairments underlie conceptualisation difficulties at the microstructural and macrostructural level. I will discuss this point in more detail later in this chapter.

The omission of essential information units was the most commonly observed symptom and often occurred as the only macrostructural symptom (see Table 1). This matches early studies that reported a reduction of important information in the discourse of people with aphasia (e.g., Huber, 1990; Ulatowska et al., 1983). However, a large number of underlying impairments could explain this symptom, as discussed in the individual discussion sections of Chapters 2 and 3.

Consequently, the other two symptoms - a large proportion of non-essential information and/or an unusual ordering - may be more informative regarding possible conceptualisation difficulties. In contrast to previous single case reports on sentence production (e.g., Byng, Nickels, & Black, 1994; Cairns et al., 2007; Marshall et al., 1993), none of the participants in this thesis produced an unusual amount of detail in their picture descriptions (e.g., clothes of depicted entities, objects in the background). The non-essential information produced by the participants included in this thesis was most commonly categorised as either comments or plausible ideas. However, one participant with svPPA (S14) was identified, whose large number of irrelevant comments about the Cookie Theft picture (e.g., "I wonder why it's leaking") suggested difficulties in focusing on the main events in a scene as was previously reported for Ron (Cairns et al., 2007).

Table 1: Symptom patterns of those participants with stroke-induced aphasia (50 participants in total; Chapter 2) and PPA (60 participants in total; Chapter 3) who showed any of the investigated macrostructural symptoms

Participant group	% (number)	**Main concepts**	**Non-main concepts**	**Order of main concepts**
		Significantly reduced	Significantly increased	switching
Stroke	28.3% (17)	X		
PPA	32% (16)	X		
Stroke	11.7 % (7)	X	X	
PPA	2% (1)	X	X	
Stroke	6.7% (4)		X	
PPA	14% (7)		X	
Stroke	1.7% (1)	X		X
PPA	12% (6)	X		X
Stroke	1.7% (1)		X	X
PPA	4% (2)		X	X
Stroke	0% (0)	X	X	X
PPA	2% (1)	X	X	X
Stroke	1.7% (1)			X
PPA	0% (0)			X

An unusual order of main information in the participants' discourse was the least commonly observed symptom across participants. It seems unlikely that linguistic impairments alone could account for this symptom. Therefore, of all the macrostructural symptoms investigated in this thesis, an unusual sequence of main concepts and/or temporal sequencing errors seemed the most reliable predictors for more general cognitive conceptualisation difficulties (e.g., Carragher et al., 2015; MacDonald, 2013; Manning & Franklin, 2016; Schultze-Jena, 2001) as previously discussed in the Discussion sections of Chapters 2 and 3.

While more than 50% of the participants in both studies showed at least one macrostructural symptom, the results also suggest that symptoms that specifically indicate problems with conceptualisation (i.e., sequencing errors) only occur in a few cases. Similarly, few cases with presumed conceptualisation difficulties at a microstructural level ('Thinking for Speaking' deficits) have been described in the literature (e.g., Byng et al., 1994; Cairns et al., 2007; Dean & Black, 2005; Dipper, Black, & Bryan, 2005; Marshall et al., 1993).

Overall, the findings presented in Chapters 2 and 3 provide some evidence that conceptualisation difficulties, which may be associated with more general cognitive disorders such as attention or working memory impairments, may underpin the observed macrostructural symptoms of some participants with stroke-induced aphasia and PPA. The results also show that the investigation of macrostructural symptoms is an important part of discourse analysis, and one that allows a more holistic impression of the participants' symptom patterns to be gained.

However, in order to reliably diagnose conceptualisation difficulties on the basis of observed macrostructural symptoms, it is important to learn more about how other possible impairments may influence the macrostructural organisation of a speakers' picture description. Word retrieval difficulties and/or an impaired lexical access are the most commonly suggested possibilities as a cause of a reduction of essential information, and that may also contribute to the occurrence of other observed macrostructural symptoms (e.g., Andreetta et al., 2012; Christiansen, 1995; Huber, 1990; Ulatowska et al., 1983). To investigate how restricted word access in the absence of other general cognitive or language impairments influences the macrostructure of discourse, **Chapter 4** used the 'taboo-paradigm' (c.f., Meffert et al., 2011) as a novel approach to reduce word availability in unimpaired speakers and compared their results to the macrostructural symptoms observed in speakers with lexical access impairments as a consequence of aphasia.

While the majority of control participants reduced the number of main concepts in their taboo description and produced minor order changes, none showed symptoms that altered or impaired the overall semantic connectedness of the ideas stated in the picture description (coherence; Redeker, 1990) compared to the unconstrained condition. Interestingly, 62% of the main concepts omitted by the controls could have been produced without using any of the tabooed words. With regard to the participants with aphasia investigated in this study, we found that 5 of the 12 participants with aphasia and lexical retrieval impairments showed macrostructural symptoms that were not (or were rarely) observed in unimpaired controls. Specifically, they omitted multiple essential main concepts (mentioned by 100% of controls during unconstrained description) and produced their main concepts in an order that was different to any control participant.

While the results of the study presented in Chapter 4 generally support the idea that a limited word availability influences, to some degree, the amount and order of information units the participants choose to convey in a picture description task, it did not seem to be the case that the participants simply omitted main concepts containing words they were not allowed to say (e.g., Andreetta et al., 2012; Christiansen, 1995). Moreover, the macrostructural symptoms observed in about half of the participants with aphasia showed marked qualitative differences compared to unimpaired participants (e.g., omission of essential information, temporal sequencing errors). I propose three different possible explanations for this finding:

1) the elicited impaired word availability was not sufficiently severe to affect the macrostructure of the control participants' discourse in the same way as these people with aphasia;

2) control participants used their cognitive resources to cope with the limited word availability and avoided profound changes in the macrostructure in a way that people with aphasia could not;
3) lexical deficits alone cannot account for the observed macrostructural symptoms in some of the participants with aphasia (see also, Cairns et al., 2007; Manning & Franklin, 2016; Marshall et al., 1993).

Previous reports on conceptualisation and 'Thinking for Speaking' impairments in aphasia have suggested an underlying event processing deficit (e.g., Byng et al., 1994; Cairns et al., 2007; Dean & Black, 2005; Marshall et al., 1993). In contrast, the results of the studies presented in Chapter 2 and 4 suggest that neither event processing nor verb retrieval deficits have substantial influence on the speakers' performance at the macrostructural level. This was because, at a group level, there were no significant correlations between non-verbal event processing skills and the number or order of main concepts (Chapter 4) and only a moderate association between action naming skills and the number of main concepts (Chapter 2). This, however, does not exclude the possibility that at an individual level, event processing deficits may have increased (if not caused) the observed discourse impairments at the macrostructural level (see case ANT, Chapter 4).

While the results of the first three studies suggest impairments of the conceptualisation process at the macrostructure level in some participants, discourse analysis approaches are limited in their ability to assess whether macrostructural planning is intact or not. Therefore, in **Chapter 5**, I complemented the main concept analysis with an analysis of eye movements during a picture description task and evaluated the feasibility of such a technique in the investigation of conceptualisation processes. Here, I compared the eye movements of six unimpaired speakers during their preparation and execution of a picture description to one participant with aphasia (STR).

Results showed substantial consistency in the eye movements across unimpaired speakers, suggesting that similar macrostructural planning processes were taking place. The findings also replicated previously observed temporal links between eye movements and speech production (e.g., average eye-voice span about 900-1000ms, Griffin and Bock, 2000). Furthermore, the eye tracking paradigm was sufficiently sensitive to detect differences between the eye movement patterns of control participants and STR, which provide more information about the underlying mechanisms of the observed macrostructural differences in his picture description (e.g., temporal sequencing errors). Although STR's eye movements also seemed to be driven by linguistic processes (e.g., word retrieval), observations like the large delay in his fixation on the critical main event and his prolonged eye-voice span (about 2000ms), suggested generally slowed conceptualisation and increased planning effort during picture description (see, Holsanova, 2008). Overall, the results presented in Chapter 5 motivate the use of eye tracking for further research on conceptualisation difficulties in people with neurological language impairments and showed that the analysis of eye movements can be particularly useful to investigate the underlying mechanisms of temporal sequencing deficits (see Chapter 2, 3 and 4) in further research.

Theoretical Implications

The research presented in this thesis was inspired by previous work investigating deficits of 'Thinking for Speaking' (Slobin, 1996) in participants with aphasia (Black & Chiat, 2000; Cairns et al., 2007; Dean & Black, 2005; Dipper et al., 2005; Marshall, 2009). However, the approach taken to investigate conceptualisation processes in participants with neurological language impairments differs from the traditional understanding of 'Thinking for Speaking' impairments (Black & Chiat, 2000; Dipper et al., 2005). This thesis aimed to extend this literature by investigating the presence and nature of conceptualisation difficulties at the macrostructural level in the same population reported in the 'Thinking for Speaking' literature – people with stroke-induced aphasia (Chapter 2) and extend it to people with neurodegenerative language impairments (Chapter 3).

The 'Thinking for Speaking' literature proposed difficulties attending to, or processing linguistic specifics of an event (e.g., tense, how many participants involved, direction of an action; c.f., Slobin, 1996), as the possible impairment underlying the observed symptoms at the microstructural level (e.g., hypernaming; Cairns et al., 2007). Levelt (1989), suggests an, at least partly sequential, conceptualisation process in which macroplanning takes place prior to microplanning. This idea has been confirmed by eye tracking studies investigating processes of sentence and discourse generation in unimpaired speakers (Griffin & Bock, 2000; Holsanova, 2008) and was replicated by the results in Chapter 5 of this thesis. In more complex discourse, the boundaries between macro- and microplanning processes become less distinct (Levelt, 1999). For example, perspective taking, a process that takes place at the microstructural level according to Levelt (1989), can also be performed at macrostructural level (e.g., by repeating phrases that should be emphasised; Labov, 1972). This shows that both processes are highly interlinked. Consequently, the same underlying impairments as have previously associated with microstructural 'Thinking for Speaking' symptoms, might also account for observed difficulties in organising discourse at the macrostructural level. If, for example, a speaker is unable to identify the main event in a picture stimulus, subsequent processing steps, like selecting relevant information (macroplanning) and selecting the most appropriate verb to convey the speaker's perspective (microplanning; Cairns et al., 2007), also cannot be accurately executed.

Chapter 2 of this thesis demonstrated that some speakers with stroke-induced aphasia showed deficits in the macrostructural organisation of their discourse. Additionally, an association between verb production difficulties (as represented by the Verb Naming Test and number of verbs) and a reduced number of main concepts in stroke-induced aphasia was observed. In future studies, it would be important to investigate whether participants with impaired verb production and a reduced number of main concepts also show difficulties at the sentence level, which are similar to those reported in the 'Thinking for Speaking' literature (e.g., Cairns et al., 2007). An additional analysis of these participants' non-verbal event processing would also be recommended to confirm the argument that symptoms described in the 'Thinking for Speaking' literature and macrostructural deficits in discourse might, in some cases, be underpinned by the same (non-verbal/event processing) impairment. Furthermore, such an investigation would be necessary to confirm the hypothesis that macrostructural deficits add an additional layer to the traditional 'Thinking for Speaking' account and that we should therefore distinguish conceptualisation impairments at the macrostructural or microstructural level, as I have proposed in this thesis.

The studies presented in this thesis further extend the current literature by showing that conceptualisation difficulties at the macrostructural level do not only occur in speakers with a primarily agrammatic symptom pattern as suggested in the 'Thinking for Speaking' literature. Indeed, it seems plausible that microstructural conceptualisation impairments caused by linguistic difficulties (e.g., tense, determining argument structure) occur predominantly in speakers with non-fluent/agrammatic aphasia. Interestingly, the study presented in Chapter 2 shows that the participant with stroke-induced aphasia who showed all three macrostructural symptoms investigated in this thesis, was diagnosed with semantic impairments and Wernicke type aphasia. This seems to suggest that macrostructural deficits observed in some participants reported in this thesis, are caused by different underlying impairments to the traditional 'Thinking for Speaking' difficulties reported in the literature (Cairns et al., 2007; Dipper et al., 2005). Macrostructural planning of discourse requires correct semantic processing of the event, otherwise processing steps like the most appropriate selection of information would not be possible (Levelt, 1989). Participants with Wernicke's type aphasia present with predominantly verbal semantic deficits that may in part explain the observed difficulties in conceptualising and realising a coherent description of a complex event scene.

The inclusion of participants with a neurodegenerative form of aphasia (PPA) allowed a further investigation link between semantic deficits and conceptualisation difficulties. Particularly participants with svPPA are characterised by a profound loss of verbal and non-verbal semantics. Indeed, the study presented in Chapter 3 showed that numerically more participants with svPPA than nfvPPA or lvPPA produced a large proportion of non-essential information and/or reduced amount of essential information (see Chapter 3, Table 11).

The investigation of participants with PPA further showed that difficulties directing and/or maintaining attention on events or entities that are important in a scene and/or other more generalised cognitive deficits (e.g., working memory) may represent a possible alternative explanation for the observed macrostructural symptoms. The processes involved in the transformation of thoughts into spoken language are heavily influenced by more general cognitive constraints including the speaker's attention and memory capacities (Levelt, 1989).

As outlined in Chapter 3, the constant switching between foci (MOTHER and CHILDREN) in the Cookie Theft picture may best be explained by an impairment in keeping focussed on one side of the picture. Similarly, the participant with svPPA who showed the largest proportion of non-essential information, seemed to exhibit severe difficulties in maintaining her attention on the main information of the picture (e.g., becoming distracted and saying "I wonder why it's leaking."). Working memory difficulties might cause the speaker to lose track of his/her conceptualisation of the picture description which could result in disorganised macrostructure (MacDonald, 2013). Chapter 3 demonstrates a significant association between a reduced digit span and a reduced number of main concepts in participants with nfvPPA which further support this hypothesis for some people with PPA.

Importantly, while the non-essential information mentioned by the participant with svPPA were comments about the scene, some speakers with stroke-induced aphasia (Chapter 2) and PPA (Chapter 3) produced non-essential information units that resemble the overly detailed description (i.e., hypernaming) reported by Cairns et al., (2007; for participant Ron). For example, one participant in the study presented in Chapter 2 describes that "the tree has long skinny branches". In line with Cairns et al.'s (2007) hypothesis that Ron's hypernaming might be caused by difficulties to maintain attention on the main information of the picture, we would suggest, that a similar underlying problem may be present in some participants reported in this thesis. It is important to note however, that no participant in any of the studies presented in this thesis produced a remarkably overly detailed description. Statements about irrelevant details only occurred occasionally across the participants' descriptions. Interestingly, Ron, also did not produce an overly detailed discourse. Hypernaming only occurred at the sentence level, when he was asked to describe simple pictures (e.g., the fairy sprays the swimmer with a hose"; Cairns, 2006). Hence, it might also be likely that those participants who produced a rather detailed description, misunderstood the task and tried to describe the picture as detailed as possible. This argument is further in the "Methodological challenges and implications section".

Nevertheless, the results of this thesis showed that higher level cognitive impairments could indeed represent a potential underlying impairment for disturbed macrostructure in participants with stroke-induced aphasia. Levelt (1989) argues that speakers tend to order information in a way that results in the least cognitive effort for the speaker (minimal-load principle). The results presented in this thesis provide evidence that confirms this hypothesis. For example, 42% of participants with aphasia in Chapters 2 and 5, very early in their descriptions, mentioned main concepts perceived as particularly important (Chapter 5: the jacket being set alight) or that drew most attention (Chapter 2: the dog in the centre of the picture). It is possible that these participants with aphasia did so to reduce the cognitive load on their working memory. In contrast, unimpaired participants had the capacity to hold those main concepts in their working memory and only mentioned them when they fitted with the natural order of events.

The taboo-paradigm, presented in Chapter 4, induced restricted word access in unimpaired participants so that its influence on the macrostructural organisation of discourse could be studied in the absence of cognitive disorder. While a general reduction of main concepts was also observed in unimpaired speakers under the taboo condition, it is striking that some of the participants with aphasia showed a very different pattern in the disturbance to the macrostructural organisation of their discourse (e.g., omission of essential information, sequencing errors). Hence, these results support the hypothesis that linguistic deficits alone cannot explain the macrostructural symptoms observed in some participants with aphasia.

Importantly, however, the taboo-paradigm also increased the cognitive load for unimpaired speakers during their picture description (e.g., active inhibition of words). This additional cognitive effort might have also affected the macrostructural organisation of their discourse.

Some people with aphasia are known to have co-occurring broader cognitive difficulties. Attentional deficits have been particularly reported (e.g., Murray, 2012). In the context of the tasks used in this thesis, maintaining visual attention is necessary to decode the events depicted on a complex scene, which is the starting point of an appropriate conceptualisation of a picture description (Levelt, 1989). Furthermore, it is necessary to shift the attention across the scene to incorporate individual parts of the picture into a coherent description (e.g., Murray, 2012). Roelofs and Piai's (2011) computational model of word retrieval additionally demonstrated that sustained attention plays a crucial role in the conceptualisation and retrieval of specific lexical entries and attention demands are high during speech production. Importantly, Cairns et al., (2007) argue that the patient (Ron) who produced a high amount of non-essential information and information sequencing difficulties when describing a simple picture in one sentence, also might have had problems to sustain attention on the main information or pay attention to the beginning of an event.

Recently, inspired by Chris Code's work (Code, 2018), the question has even been raised whether most (if not all) language impairments observed in people with aphasia can be explained by broader cognitive deficits of attention, memory and executive functions. Based on the studies presented in this thesis, I do not make a claim as bold as this, however, the results presented here do support the idea that our models of speech production need to take into greater consideration the role of general cognitive abilities and their possible impairments in order to gain a more holistic picture of how we transform our thoughts into spoken language. For future studies it would be necessary to complement the main concept analysis conducted in this thesis with a comprehensive neuropsychological assessment of more general cognitive skills. In particular, the investigation of visual attention, working memory and cognitive inhibition abilities would provide valuable information to further inform theories of conceptualisation and its impairment.

Methodological Challenges and Implications

Eliciting discourse using picture descriptions

The studies presented in this thesis analysed features of macrostructural organisation on the basis of complex picture descriptions. Picture description constitutes a controlled and restricted speaking situation which differs in many ways from an everyday communication situation (e.g., Armstrong, Ferguson, & Simmons-Mackie, 2013). One potential problem of the picture description task is that the speaker does not need to convey any new information since both interlocutors can see the picture that is described in front of them. Therefore, some participants might omit seemingly obvious events (see Armstrong et al., 2013), which in turn affects the number and order of main concepts that was measured in the studies presented in this thesis. This potential problem is however outweighed by the benefits of the content predictability achieved in picture description tasks. It is exactly this predictability of discourse content that was necessary to investigate the extent to which the discourse organisation of people with aphasia differs from unimpaired controls or how far general macrostructural organisation is unimpaired, even in the context of participants' expressive difficulties. Consequently, the research presented in this thesis only investigated conceptualisation for speech production from a picture, which might be less complex than conceptualisation in a conversational setting. For further research it would be interesting to develop methods that enable us to analyse the participants' conceptualisation processes in a less restricted speaking situation. However, the results of the studies presented here suggest that picture descriptions are sufficient to gain a first impression of the macrostructural conceptualisation skills of a person with aphasia without requiring any additional testing to that conducted during a standard diagnostic assessment.

In this thesis, I used a variety of stimulus pictures. Since it is known that elicited discourse can vary substantially depending on the picture stimulus and the wording of the instructions the participants are given (Olness, 2006), the specifics of the different pictures and instructions used are discussed here in further detail.

The data presented in Chapter 2 was retrieved from the AphasiaBank database (MacWhinney, Fromm, Forbes, & Holland, 2011), that used the ‘Cat Rescue’ (Nicholas & Brookshire, 1993) picture and the instruction “Please tell me what you see happening here, by telling a story with a beginning a middle and an end” (see, Olness, 2006). MacWhinney et al. (2011) decided on this wording since it emphasises that temporal and causal relations between the depicted entities and/or events should be expressed. In contrast, the more traditional instruction for picture descriptions of: “Please tell me what you see happing in the picture”, often elicits a list like very descriptive picture description (e.g., on the left I see X; right next to it is Y). Since the participants may have experienced this standard instruction in previous assessment sessions, it may be necessary to prepare participants for this new kind of picture description (e.g., example description by instructor). Unfortunately, the AphasiaBank protocol did not include explicit training of the required narrative picture description response. Nevertheless, most participants sampled from AphasiaBank and reported in Chapter 2 did try to link the depicted events either verbally or by pointing (e.g., pointing from girl to cat to communicate the link between these entities). It is, however, possible that some participants had difficulties adjusting to this new task and produced a less coherent story about the picture than they might have been capable of. Consequently, this may have affected the main concept analysis for some participants in this study.

In the studies presented in Chapters 4 and 5, I used newly developed pictures. Similar to the ‘Cat Rescue’ picture, these followed the criteria of a complex picture summarised by Olness (2006): a complex picture depicts “a complication or climax” whose “meaning can be interpreted only through a synthesis of relationship between and among actors and their actions” (Olness, 2006, p. 177). Additionally, I used the same instruction wording used in the AphasiaBank protocol and trained the required picture description response with each participant as Olness (2006) proposed. I believe that following such a rigorous protocol contributed to the large degree of agreement in the main concepts that were produced, and in the main concept order, that I observed across the control participants in both studies.

The data I presented in the study of Chapter 3 was kindly provided by FRONTIER the frontotemporal dementia research group in Sydney. Their standard diagnostic protocol contained the widely used 'Cookie Theft' picture (Goodglass et al., 1983) together with the task instructions: "Tell me what you see going on/ happening in the picture". Hence, in contrast to the other studies in this thesis, the production of narrative discourse was not particularly encouraged by this protocol. A similar protocol was used to elicit 'Cookie Theft' picture descriptions for the main concept analysis presented by Nicholas and Brookshire (1995). Therefore, while different to other studies in my thesis, this instruction wording ensured better comparability of my results to the work presented by Nicholas and Brookshire (1995).

Importantly, however, the analysis of the order of main concepts was less successful in this study. Although I agree with Olness (2006) that the 'Cookie Theft' is an example of a complex picture, it differs from the pictures used in the other studies in this thesis. As discussed in Chapter 3, the picture depicts two, relatively unlinked, main events (sink overflowing; boy stealing cookies; see also Olness, 2006). Indeed, the majority of people described one event completely before moving to the other. However, the picture suggests no natural order of these two main events: half of the participants decided to start with the 'overflowing sink' while the other half started by mentioning the children stealing the cookies. Consequently, only major order changes (i.e., alternating statements about each main event) could be identified in this analysis.

Overall, the 'Cookie Theft' seems to be a less suitable picture stimulus for an analysis that focuses on the macrostructural organisation of discourse. Instead, for future research, I would recommend the use of complex pictures like the 'Cat Rescue' (Nicholas & Brookshire, 1993) that follow the criteria for a complex picture outlined by Olness (2006).

Variability in main concept analysis approaches

Since the introduction of main concept analysis by Nicholas and Brookshire (1993, 1995), there have been several modifications to their original approach (e.g., Capilouto, Wright, & Wagovich, 2005; Richardson & Dalton, 2016; Tanaka, Branch, Dalton, & Richardson, 2016). The studies presented in this thesis complemented Nicholas and Brookshire's (1995) traditional approach with the analysis of non-main concepts and the order in which main concepts were produced. Therefore, the work presented in this thesis adds a new main concept analysis approach to the literature that provides a more holistic impression of the macrostructural organisation of an individual's discourse.

However, there has been great variability in the methodological details of the main concept analyses reported in the literature. In particular, different studies have used different thresholds for classification of a statement as a main concept. These thresholds ranged from 33% to 70% of participants needing to mention a statement for it to be included as a main concept (e.g., Capilouto et al., 2005; Nicholas & Brookshire, 1995; Richardson & Dalton, 2016). This variability can also be found in the studies presented in this thesis. However, each of the different thresholds reported in Chapters 2, 3 and 4 were motivated by precedents from the literature.

Studies that established main concepts on the basis of a small sample of participants generally chose higher thresholds (66%-70%; Capilouto et al., 2005; Nicholas & Brookshire, 1995). I followed this approach, in the studies described in Chapter 4 and 5 which present data from the newly developed picture material and established main concepts on the basis of picture descriptions from only 20 participants. Therefore, a strict 70% criterion seemed suitable to ensure that only the most essential information units were included in the list of main concepts (see, Nicholas & Brookshire, 1995).

Chapter 3 used the same stimulus picture as Nicholas and Brookshire (1995), and therefore I aimed to follow their procedure and started by identifying statements that were mentioned by 70% of unimpaired participants. However, one main concept identified by

Nicholas and Brookshire ("the boy is on the stool") was only produced by 55% of participants in my study. Hence, I decided to use a 55% threshold to include all Nicholas and Brookshire's main concepts identified by. The use of this lower threshold resulted in inclusion of two additional main concepts that contained information about the garden or the kitchen depicted in the 'Cookie Theft' scene. It is possible that these statements would have been disregarded by Nicholas and Brookshire (1995), since a statement about, for example, the cupboard in the kitchen does not seem "essential information" (Nicholas & Brookshire, 1995, p.148). However, the fact that 60% of unimpaired participants in my study mentioned the garden or described the kitchen in greater detail was both important and informative for my non-main concept analysis. This prevented me from overinterpreting a description that provided these details as a symptom of possible conceptualisation difficulties, given that an unusual amount of detail was proposed to be a key symptom of conceptualisation difficulties (Cairns et al., 2007; Marshall, 2009).

For the main concept analysis presented in Chapter 2, I also implemented a different threshold to identify main concepts in the participants' picture descriptions. Here, I established the list of main concepts on the basis of a large sample of 50 picture descriptions. Richardson and Dalton (2016) argue that a 70% threshold is unnecessarily strict when main concepts are established on the basis of a large number of participants. Considering the natural variability of speech production, Richardson and Dalton (2016) and Tanaka et al. (2016) suggested a comparatively low 33% threshold for the identification of main concepts. Nevertheless, Richardson and Dalton also proposed 50% and 60% as possible thresholds for identifying main concepts in. Since 33% seemed very low given the general predictability of discourse content elicited by a picture description, and the criteria used in other studies, I decided to use the highest percentage they proposed 60%. Reassuringly, both the 33% (Tanaka et al., 2016) and 60% (Chapter 2) thresholds resulted in a similar number and content of main concepts for the 'Cat Rescue' picture description. In combination with the findings from Chapter 3, this suggests that the precise threshold may not be critical and adaptation of the threshold is appropriate depending on the stimulus picture, the size of the sample and the focus of the analysis (e.g., just main concepts vs. main concepts and non-main concepts). Future studies which evaluate the use main concept analysis for clinical populations, could investigate this further.

Main concept analyses present an attempt to measure the amount of important information in the speaker's discourse. However, conceptualisation is a highly individual process. What a speaker defines as important depends on his/her interpretation of the scene (e.g., Nicholas & Brookshire, 1995). Hence, a measure of important information can only be limited in its general application. The large variability in thresholds (% of controls to produce an idea) used to define the main ideas in a picture description across the literature demonstrate the effort to capture natural variability of spontaneous speech. Despite this variability, main concept analyses provide a good overview of what unimpaired speakers generally consider important enough to be mentioned in their picture description. Therefore, it represents a valid method to investigate similarities and differences in the information selection of unimpaired speakers and speakers with aphasia.

Eye tracking with clinical and elderly populations

Conducting an eye tracking study with a clinical and/or elderly population results in natural and unavoidable obstacles. For example, while it is generally argued that testing participants with glasses is possible with the eye tracking system used in this study (EyeLink1000, SR Research, 2010), I experienced profound difficulties in tracking the pupil of participants who wore glasses. Indeed, although it depended in part on the type of glasses the participants are wearing (e.g. single vs multifocal), eye tracking success was so variable overall that the decision was made to exclude participants with glasses from this study. When investigating eye movements in an elderly population, either healthy or with neurological language impairments, the likelihood that potential participants will need glasses to perform the task increases. This poses a potential problem for the recruitment of participants for future studies.

The pilot study presented in this thesis included participants who reported that the did not have any visual impairments. Nevertheless, an additional visual screening to confirm that the participants' vision is appropriate for the task would have been a valuable addition to the testing protocol. Previous studies that included participants with aphasia as well as unimpaired controls have screened for central visual acuity and visual neglect (e.g., line bisection, clock drawing test) to gain more detailed information about the participants vision (e.g., Heuer & Hallowell, 2015). Similar testing should be included in future eye tracking studies.

Testing participants with neurological language impairments may lead to additional hurdles. For example, one participant, ALM, who initially participated in the study presented in Chapter 5, showed quite severe impairments of his general mobility. Using the remote eye tracking system of the EyeLink 1000 (SR Research, 2010), it was possible for him to remain in his wheelchair. However, he had difficulties maintaining an upright position during the testing session, resulting in his eyes frequently moving out of the trackable area. In addition, ALM had the habit of closing his eyes every time he had difficulties retrieving a word. Therefore, for ALM critical eye movement data could not be obtained and he had to be excluded from the study. The results of my study suggest that it might be difficult to obtain reliable eye movement data from severely impaired and partially immobile participants. This needs to be considered when planning studies in the future.

Clinical Implications

One of the main aims of this thesis was to develop a practical and clinically applicable method to identify possible conceptualisation difficulties at the macrostructural level in participants with neurological language impairments. Consequently, this thesis presents a comprehensive list of main concepts and their most usual order for two commonly used diagnostic pictures: the 'Cat Rescue' (Nicholas & Brookshire, 1993; see Chapter 2) and the 'Cookie Theft' (Goodglass et al., 1983; see Chapter 3). Both sets of main concepts were consistent with previous research (Nicholas & Brookshire, 1995; Tanaka et al., 2016) and therefore could be used confidently by clinicians to provide a checklist that would give a first impression of the informativeness and macrostructural organisation of a speaker's discourse in everyday clinical practice.

The thesis further presents normative data from large samples of unimpaired speakers as well as speakers with stroke-induced aphasia (Chapter 2: 'Cat Rescue' picture) and PPA (Chapter 3: 'Cookie Theft' picture). This data can be efficiently used as norms which a clinician can use to compare with the performance of an individual with language impairment (e.g., using Crawford single case statistic tool 'Singlims'; Crawford, Garthwaite, Azzalini, Howell, & Laws, 2006).

The results presented in the studies of Chapters 2, 3, and 4 further suggest that a profoundly different main concept order and temporal sequencing errors constitute a strong indicator for underlying conceptualisation difficulties. Hence, the occurrence of this symptom can be used to motivate further neuropsychological assessments of the speaker's attention, working memory and executive skills, to establish which deficit impairs the speaker's ability to conceptualise his/her discourse and to develop a suitably targeted therapy program.

Additionally, this thesis clearly outlines the benefits and disadvantages of the 'Cat Rescue' and 'Cookie Theft' picture for the investigation for macrostructural features of discourse (see Chapter 2 and 3). I selected these picture stimuli for the research of this thesis, because they are widely used to elicit monologue discourse from speakers with aphasia. However, this also bears the risk that some speakers with aphasia, particularly in chronic stages, may be very familiar with these pictures so that their descriptions do not quite represent their true discourse abilities. Hence, this thesis advocates for the need for new picture material that elicits descriptions of similar complexity and structure a similar and can be used for future research and clinical practice.

To address this issue, the study in Chapter 4 presented a set of newly developed picture material. The first evaluation of these stimuli showed a large consistency in the elicited picture descriptions across participants. Of course, further evaluations will be necessary to confirm these results. Nevertheless, this new material shows a great potential as a diagnostic tool that will facilitate reliable investigation of macrostructural features of discourse and track a speaker's discourse performance across time (e.g., evaluate therapy effectiveness).

In sum, this thesis presents key symptoms of conceptualisation deficits at the macrostructural level and provides clinicians with valuable tools to efficiently identify them in the discourse of speakers with neurological language impairments to inform further diagnosis and therapy.

Conclusion

At the beginning of this thesis I introduced two speakers with agrammatic aphasia: George and Sarah. Their profoundly different experience of a seemingly similar language impairment sparked the questions: *Is it possible that the language impairments of some individuals with aphasia are underpinned by broader speech planning (conceptualisation) difficulties? What symptoms would indicate such an underlying conceptualisation impairment?* and *How can we best diagnose it?* The studies presented in this thesis found preliminary answers to each of these questions and made several theoretical, methodological and clinical contributions to current literature of conceptualisation deficits and discourse analysis in speakers with neurological language impairments.

First, this research demonstrates that macrostructural deficits occur more frequently in the discourse of speakers with stroke-induced and primary progressive aphasia than previously reported in the literature. Second, it has identified that an atypical order of main concepts and occurrence of temporal sequencing errors are strong indicators for underlying conceptualisation difficulties and which motivate further, primarily neuropsychological, diagnostic assessments in those participants who show such symptoms. Third, this research extended previous main concept analysis approaches to develop a discourse analysis method that can be used to investigate the speaker's macrostructural abilities and resources particularly in speakers with profound expressive impairments. Fourth, new complex pictures have been presented with great potential to complement the established pictures used in the assessment of monologue discourse in speakers with neurological language impairments. Finally, this thesis presents pioneering work evaluating the feasibility of eye tracking as possible objective method to investigate conceptualisation processes in a complex picture description. Once again, this method proved to be particularly valuable to gain information about the conceptualisation resources of individuals with profound speech production impairments and motivates the use of eye tracking for further research in this field.

I hope the findings presented in this thesis will guide future studies on conceptualisation difficulties and facilitate their clinical diagnosis enabling therapists to provide the best possible therapy to help people like George and Sarah to express their thoughts.

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334.

Appendices

Ethics Approval - Macquarie University (Australia)

Ethics Approval - University of Groningen (Netherlands)

Ethics Approval - Medical Faculty of the Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen (Germany)

Office of the Deputy Vice-Chancellor (Research)

Research Office
C5C Research HUB East, Level 3, Room 324
MACQUARIE UNIVERSITY NSW 2109 AUSTRALIA

Phone **+61 (0)2 9850 4194**
Fax +61 (0)2 9850 4465
Email ethics.secretariat@mq.edu.au

26 March 2014

Professor Lyndsey Nickels
Department of Cognitive Science
Faculty of Human Sciences
Macquarie University
NSW 2109

Dear Professor Nickels

Re: Understanding language processing, its breakdown and treatment (Ref: 5201200905)

Thank you for your amendment request. Your amendment request was reviewed by the Executive of the Human Research Ethics Committee (HREC) (Human Sciences and Humanities). Ethical approval has been granted to the following amendment:

1.The addition of the following personnel to the project: Ms Inga Hameister (Endeavour Research Fellow) and Dr Amanda Miller Amberber (Research Officer).

2. The addition of recruitment via an advertisement posted on social media sites including Facebook and Twitter. A link to the “Participate in MQ Research” Facebook group page will be posted by approved researchers on the project on their personal Facebook, Twitter and/or LinkedIn accounts.

The following documentation submitted with your amendment request has been reviewed and approved by the Executive of the HREC (Human Sciences and Humanities):

Documents reviewed	Version no.	Date
Macquarie University HREC Request for Amendment Form	2.0	Jan 2014
Social media advertisement		

Please ensure that in all future correspondence with the HREC all documentation has a version number and date.

Please do not hesitate to contact the Ethics Secretariat should you have any questions regarding your ethics application.

The HREC (Human Sciences and Humanities) wishes you every success in your research.

Yours sincerely

Dr Karolyn White
Director, Research Ethics & Integrity
Chair, Human Research Ethics Committee (Human Sciences and Humanities)

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2007) (the National Statement) and the CPMP/ICH Note for Guidance on Good Clinical Practice.

university of groningen

faculty of arts

commissie ethische
toetsing onderzoek (ceto)
research ethics committee

prof. dr. J.C.J. Hoeks
ceto@rug.nl

To Whom it May Concern

Date
28 March 2017

Our reference

Dear Sir/Madam,

The Research Ethics Committee (CETO) of the Faculty of Arts, University of Groningen has reviewed the proposal *'Conceptualisation and influencing factors in healthy speakers* (45061539) submitted by *Inga Hameister*. The CETO has established that the research protocol follows internationally recognized standards to protect the research participants. We therefore have no objection against this proposal.

Respectfully yours,

prof. dr. J.C.J. Hoeks

ETHIK-KOMMISSION AN DER MEDIZINISCHEN FAKULTÄT
DER RHEINISCH-WESTFÄLISCHEN TECHNISCHEN HOCHSCHULE AACHEN
Pauwelsstr. 30, 52074 Aachen - Tel. 0241-80 89 963 – FAX 0241-80 82 012
E-Mail: ekaachen@ukaachen.de

Ethik-Kommission an der Medizinischen Fakultät
der RWTH Aachen – Pauwelsstr. 30 – D - 52074 Aachen

Aachen, den 19.10.2017

Herrn
Dr. med. Cornelius Werner
Klinik für Neurologie
im Hause
cwerner@ukaachen.de

nachrichtlich an:
Univ.-Prof. Dr.med. Jörg B. Schulz, Klinik für Neurologie, jschulz@ukaachen.de

Schmal/ah

Betrifft:

EudraCT-Nr.	-
Protokoll-Nr:	-
Titel:	Konzeptualisierungsdefizite bei Aphasie.
Sponsor:	-
Eingereicht von:	Dr. med. Cornelius Werner, Klinik für Neurologie, Uniklinik RWTH Aachen, Pauwelsstraße 30, 52074 Aachen
Antragsteller:	Beate Schumann, Logopädische Koordination, Klinik für Neurologie, Universtätsklinikum Aachen, Pauwelsstraße 30, 52074 Aachen
LKP:	-
Lokaler Hauptprüfer:	Dr. med. Cornelius Werner, s.o.
Internes Aktenzeichen:	**EK 228/17**

Hier: Anschreiben zum Votum

Sehr geehrter Herr Dr. Werner,

Sie haben bezüglich der o. g. Studie um eine Beratung durch die Ethik-Kommission an der hiesigen Medizinischen Fakultät der RWTH Aachen gebeten. Als Anlage übersende ich Ihnen das Votum mit der Bitte um Kenntnisnahme.

Bitte beachten Sie insbesondere auch die spezifische Auflage zur Teilnehmerinformation.

Für das Forschungsvorhaben wünschen wir Ihnen viel Erfolg.

Mit freundlichen Grüßen

i. V. Rolf U.

Prof. Dr. med. G. Schmalzing
Vorsitzender

Anlage

Prof. Dr. G. Schmalzing, Vorsitzender; Geschäftsstelle: Tel. +49 241 80 89 963,
Fax +49 241 80 82 012; E-mail:ekaachen@ukaachen.de, Homepage: www.medizin.rwth-aachen.de/EK

ETHIK-KOMMISSION AN DER MEDIZINISCHEN FAKULTÄT
DER RHEINISCH-WESTFÄLISCHEN TECHNISCHEN HOCHSCHULE AACHEN
Pauwelsstr. 30, 52074 Aachen - Tel. 0241-80 89 963 – FAX 0241-80 82 012
E-Mail: ekaachen@ukaachen.de

VOTUM

zu dem Forschungsantrag

EudraCT-Nr.	-
Protokoll-Nr:	-
Titel:	Konzeptualisierungsdefizite bei Aphasie.
Sponsor:	-
Eingereicht von:	Dr. med. Cornelius Werner, Klinik für Neurologie, Uniklinik RWTH Aachen, Pauwelsstraße 30, 52074 Aachen
Antragsteller:	Beate Schumann, Logopädische Koordination, Klinik für Neurologie, Universtätsklinikum Aachen, Pauwelsstraße 30, 52074 Aachen
LKP:	-
Lokaler Hauptprüfer:	Dr. med. Cornelius Werner, s.o.
Internes Aktenzeichen:	**EK 228/17**

vom 03.07.2017 und 12.09.2017, eingegangen bei der Ethik-Kommission am 18.07.2017 und 19.09.2017 mit folgenden Unterlagen:

Liste der eingereichten Unterlagen mit Versionsnummern:

- Anschreiben vom 03.07.2017
- Antragsformular für Andere Studien vom 03.07.2017
- Einwilligungserklärung Kontollprobanden (ohne Versionsangabe)
- Einwilligungserklärung Patienten (ohne Versionsangabe)
- Patienteninformation (ohne Versionsangabe)
- Probandeninformation (ohne Versionsangabe)
- Prüfplan (ohne Versionsangabe)

Nachreichung vom 12.09.2017, eingegangen am 19.09.2017

- Anschreiben vom 12.09.2017
- Einwilligungserklärung (ohne Versionsnummer) (tracked changes)
- Teilnehmerinformation (ohne Versionsnummer) (tracked changes)
- Prüfplan vom 12.09.2017

Der Antrag wurde unter Beteiligung von Herrn Professor Dr. med. G. Schmalzing als Vorsitzenden und den Mitgliedern Prof. Dr. med. G. Jakse sowie Richter a. D. Franz, PD Dr. med. R. Hausmann und B. Benders beraten und wie folgt bewertet:

Prof. Dr. G. Schmalzing, Vorsitzender; Geschäftsstelle: Tel. +49 241 80 89 963,
Fax +49 241 80 82 012; E-mail:ekaachen@ukaachen.de, Homepage: www.medizin.rwth-aachen.de/EK

Gegen das Forschungsvorhaben sind aus ethischer und berufsrechtlicher Sicht keine Bedenken zu erheben.

Die Bewertung ist für folgende Prüfer und Prüfstelle gültig:

Prüfstelle:

- **Klinik für Neurologie, Uniklinik RWTH Aachen, Pauwelsstr. 30, 52074 Aachen**
- **Dr. med. Cornelius Werner [Hauptprüfer]**
- **Beate Schumann**
- **Inga Hameister**

Für dieses Votum gelten die nachfolgenden Auflagen und Empfehlungen (von deren Erfüllung die Wirksamkeit der zustimmenden Bewertung abhängt, **geforderte Korrekturen in den Unterlagen sind als Papierversion sowie elektronisch mit deutlicher Kennzeichnung der Änderungen einzureichen**):

1. Spezifische Auflagen:

a. **Teilnehmerinformation: Der erste Satz unter dem Punkt Versicherung (S. 5) „ Die Haftpflichtversicherung des Universitätsklinikum Aachen wurde bei der Allianz Versicherungs-AG …" sollte ersatzlos gestrichen werden.**

2. Allgemeine Auflagen:

a. Die Ethik-Kommission bittet darum, Mitteilungen über schwerwiegende und unerwartete unerwünschte Ereignisse, die während der Studie auftreten und welche die Sicherheit der Studienteilnehmer oder die Durchführung der Studie beeinträchtigen könnten, zu übersenden, mit einer Stellungnahme, ob sich damit die Nutzen/Risiko-Relation des Forschungsvorhabens verändert hat.

b. Ethisch relevante Änderungen im Prüfplan und in der Phase der Umsetzung sind der Kommission mitzuteilen; geänderte Passagen sollten deutlich kenntlich gemacht werden.

c. Der Antragsteller hat sicherzustellen, dass die Akten und Unterlagen nach dem Abschluss des Vorhabens in seinem derzeitigen Arbeitsbereich verwahrt und ordnungsgemäß verwaltet werden.

d. Der Antragsteller eines Zentrums hat dafür Sorge zu tragen, dass alle nachrangig in die Studie involvierten ärztlichen Mitarbeiter angemessen qualifiziert sind. Dies gilt auch für die erforderlichen Kenntnisse des Studienprotokolls.

3. Hinweise:

Prof. Dr. G. Schmalzing, Vorsitzender; Geschäftsstelle: Tel. +49 241 80 89 963,
Fax +49 241 80 82 012; E-mail:ekaachen@ukaachen.de, Homepage: www.medizin.rwth-aachen.de/EK

a. Es wird darauf hingewiesen, dass unabhängig vom Beratungsergebnis der Ethik-Kommission die ethische und rechtliche Verantwortung für die Durchführung einer klinischen Prüfung beim Leiter der klinischen Prüfung und auch bei allen an der Prüfung teilnehmenden Ärzten liegt.

b. Die Ethik-Kommission sollte vom Ergebnis der Studie unterrichtet werden. Im Falle einer Publikation der Ergebnisse könnte auch ein Sonderdruck eingereicht werden.

Aachen, den 19.10.2017

i. V. [signature]

Prof. Dr. med. G. Schmalzing
Vorsitzender

Die Ethik-Kommission ist nach Landesrecht konstituiert und bei den zuständigen Landesbehörden, beim Bundesamt für Arzneimittel (BfArM) sowie beim Bundesamt für Strahlenschutz (BfS) registriert. Sie berät unabhängig nach den Regeln des Weltärztebundes in der Deklaration von Helsinki über Forschung am Menschen in der Fassung von 1996 in Somerset West, nach nationalen Gesetzen, Vorschriften und der ICH-GCP-Leitlinie in der jeweils gültigen Fassung (siehe Homepage der Ethik-Kommission unter www.medizin.rwth-aachen.de/EK).

Prof. Dr. G. Schmalzing, Vorsitzender; Geschäftsstelle: Tel. +49 241 80 89 963,
Fax +49 241 80 82 012; E-mail:ekaachen@ukaachen.de, Homepage: www.medizin.rwth-aachen.de/EK