Decline and fall: A biological, developmental and psycholinguistic account of deliberative language processes and ageing

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Abstract

Background. This paper reviews the role of deliberative processes in language - those language processes that require central resources, in contrast to the automatic processes of lexicalisation, word retrieval, and parsing.

Aims. We describe types of deliberative processing, and show how these processes underpin high-level processes that feature strongly in language. We focus on metalinguistic processing, strategic processing, inhibition, and planning. We relate them to frontal-lobe function and the development of the fronto-striate loop. We then focus on the role of deliberative processes in normal and pathological development and ageing and show how these processes are particularly susceptible to deterioration with age. In particular, many of the commonly observed language impairments encountered in ageing result from a decline in deliberative processing skills rather than in automatic language processes.

Outcomes & Results. We argue that central processing plays a larger and more important role in language processing and acquisition than is often credited.

Conclusions. Deliberative language processes permeate language use across the lifespan. They are particularly prone to age-related loss. We conclude by discussing implications for therapy.

Keywords: Control of language, central executive, fronto-striate loop, language across the lifespan, deliberative language, metalinguistic processing, ageing, Parkinson’s disease, Alzheimer’s disease, speech therapy

Introduction

Language normally appears to be effortless. We usually pay no attention to the processes involved in producing and understanding language: when we speak or listen, much processing is *automatic*. Ask anyone other than a psycholinguist how they recognise or produce a word, or how they parse a sentence, and they will have little or no insight into the processes involved. Even training as a psycholinguist or speech and language therapist cannot help you to gain introspection into these automatic processes, and hence researchers need to construct increasingly complex experiments to help us understand how language works.

Much of language processing is mandatory, as the Stroop and cocktail-party effects demonstrate: not only do you not know how you recognised that word, you cannot help but recognise it. In the Stroop task (1935), participants are given a word printed in a colour, and have to name that colour; they are much faster to name the colour if the word and colour name are consistent (e.g. RED printed in red ink) than if they conflict (e.g. GREEN presented in red ink), presumably because even though reading the word is not necessary, it cannot be prevented. It is also well known that if you are at a cocktail party (although any social situation will do!) you will orient if you hear your name, even though you might have been engrossed in conversation with the person in front of you (Cherry, 1953). We can't help but process words. In Fodor's (1983) terminology, language processing is highly *modular* – distinct processing modules correspond to distinct neural structures, where input is processed automatically and mandatorily, and with the modules being largely encapsulated (although the extent of encapsulation is the basis of many of the debates in modern psycholinguistics). Even children seem to acquire language without effort and without explicit tuition – indeed, as is well known, explicit tuition is usually completely ignored.

However, important though these automatic processes are, some of the most interesting processes involved in language are not automatic. We name these non-automatic processes *deliberative processes*. They are among the least understood and studied processes in the field of psycholinguistics; indeed, it is not always even recognised that they are involved in mental activity at all. However, these processes control the inputs and the outputs of the language modules, and play a vital role in linguistic behaviour.

This paper rectifies this omission, exploring the nature and extent of deliberative language processing. We go on to emphasise how deliberative processes change across the lifespan. For reasons we shall discuss, ageing has particularly profound effects on deliberative processing. We have several aims:

1. To describe and classify subtypes of deliberative process and to relate them to general executive processes and the general cognitive architecture.
2. To show that deliberative processes play a major role in mediating and controlling skilled language performance.
3. To identify the brain regions involved in deliberative processing, and therefore to show that proper language performance depends on the integrity of areas outside the narrow confines of what are traditionally thought of as being the language centres of the left hemisphere.
4. To show that many of the language difficulties experienced by older speakers arise from frontal-lobe impairments that in turn affect deliberative processes.
5. To show that many of the linguistic impairments of speakers with neurodegenerative disorders such as Alzheimer’s and particularly Parkinson’s diseases arise from progressive disruption of central processes.
6. To discuss practical implications of impaired deliberative processing for therapy.

Deliberative processes

The role of deliberative processing has sometimes been undervalued in psychology – and particularly in the psychology of language. Deliberative processes enable us to choose which language modules are to be active and to influence their inputs; to reflect upon and manipulate the output of automatic language processors; to select strategies and make choices in language tasks; and to inhibit competing outputs and store material in working memory. They play a central role in controlling conversations. They are involved in acquiring oral and written language, and are particularly affected by normal and pathological ageing.

The notion of automaticity

The idea of "automaticity" has a long history in psychology, with the central idea being that some processing occurs without the involvement of attention. There are two types of automatic process: some processes become automatic after much repetition (the sort most studied in the visual search and skills literature) whereas others are automatic because they are hard-wired in the brain from or soon after birth. Whatever their origin, automatic processes are relatively fast, are mandatory, are unavailable to consciousness, and do not reduce our capacity for performing other tasks (that is, they do not demand attention). Researchers have named a number of dichotomies, including involuntary contrasted with voluntary, stimulus-driven contrasted with goal-driven, automatic contrasted with attentional processing, and automatic contrasted with controlled processing (Corbetta & Schulman, 2002; Posner, 1980; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Whether pure automatic processing is ever observed is debatable (Eysenck & Keane, 2005; Pashler, 1998).

What is a deliberative process?

Much of the research on language processing to date has been on fully or nearly fully automatic language processes. The processes of visual word recognition, parsing, comprehension, syntactic planning, and lexicalisation in non-brain-damaged skilled adults are normally automatic.

What characterises partially and fully deliberative processes in language? They are needed when the going gets tough; when we are thinking about what to say, or expending more effort than usual, or engaging in any sort of language planning, when reflecting about language, when making a judgement about linguistic representations, or when there is conflict. Deliberative processes are particularly heavily involved in tasks such as learning to read, second language acquisition, deliberate search of semantic memory, aspects of language comprehension (particularly making some inferences), linguistic intuitions, reflecting about our language, and virtually all experimental tasks that might be affected by strategy. In spite of their pervasiveness, however, deliberative processes are often seen as noise, and researchers may go to some considerable trouble in order to eliminate them (e.g. by minimising the effects of post-lexical processes in visual word recognition tasks). We argue that they play an essential role in language processing; without them we would not be able to acquire language, let alone use it as we do. We can recast the old “constructionist” versus “minimalist” debate (e.g. McKoon & Ratcliff, 1991) in automatic-deliberative terms: “minimal” language processing involves largely automatic processing, while more elaborate constructionist approaches involve aspects of deliberative processing.

Note that deliberative processes are not specific to language: they are central processes recruited for language use. Ullman (2004) examined how language arises from more general cognitive processes. In his declarative/procedural (DP) model, the lexicon depends on declarative memory, localised in the temporal lobes, while grammar depends on the rule-based procedural system localised in a neural system comprising frontal and sub-cortical structures. While this is an important model, we are concerned with the more general processes of how language is controlled by processes outside the language system.

Types of deliberative process

The Central Executive (CE) is responsible for the attentional control of working memory; it relies heavily (but not exclusively) on the frontal lobes. Executive processes implement top-down control of the system: they control other cognitive processes, co-ordinate the other components of the working memory system, and intervene when other processes go wrong.

The CE uses a number of executive processes (Baddeley, 1996, 2002, 2003, 2007; Shallice, 2002), primarily relating to selection, inhibition, and the focussing of attention: initiating behaviour, manipulating, prioritising, coordination, planning, retrieving information from long-term memory, selection, updating information, inhibition, organisation, sequencing, and monitoring. The list is probably not exhaustive or exclusive. Miyake et al. (2000) used a latent variable analysis to show how complex tests of executive function such as the Tower of Hanoi, random number generation, dual-tasking, and the Wisconsin Card Sorting Test (WCST) rely differentially on processes called Shifting (the ability to shift mental set), Inhibition (inhibiting unsuitable responses), and Updating (monitoring and updating information). WCST performance was related most strongly to Shifting, the Tower of Hanoi to Inhibition, and random number generation to Inhibition and Updating. Ramsberger (2005) describes the construction of measures of six executive functions (monitoring, self-regulation, planning, attention, cognitive switching and flexibility, and regulation) that minimise linguistic demands and hence that are more suitable for testing the executive skills of aphasic speakers.

Clearly then we should not think of “executive processing” as being a single, simple thing, but instead comprising a number of sub-processes, which may not have any simple linguistic label. We are concerned with the micro-processes of high-level cognition. Identifying these micro-processes is a fantastically complex task, involving the teasing apart of processing commonalities that are observed between difference language tasks . An analogy is provided by computers and programming language: our putatively low-level description of cognitive processes such as sequencing and selection corresponds to a high-level programming language, while the micro-processes of cognition correspond to Assembly language. Note also that the mapping between these micro-processes and neural structures might be complex. It is well known that one well-defined brain region can be involved in many apparently different cognitive processes (see Price & Friston, 2005, for a review). Our level of verbal description of cognitive processes (e.g. “word recognition”, “tactile object recognition”) is not one with which the brain is familiar. Instead, these complex processes recruit cognitive micro-processes that may be involved in many different high-level processes. We recognise that claims such as “damage to the frontal lobes leads to impairments of deliberative processes, which in turn lead to impairments of controlling language” are vague. Nevertheless, as we do not know what these micro-processes might be, we can do no better than to use the conventional terms while bearing in mind that terms such as “selection” and “planning” are short-hand, and may have no distinct neurological correlates.

We can still broadly identify how some executive processes might be particularly heavily involved in types of language processing. Given the list above, planning utterances involves initiating behaviour, prioritisation, sequencing, and planning; reflecting on language and tasks such as phonological awareness involves manipulating units and prioritising; both production and comprehension heavily involve coordination, retrieving information from long-term memory, and inhibition; and comprehension involves updating in the light of new information. Language production particularly involves monitoring our utterances. This list is not meant to be exhaustive.

Deliberative processes in action

In this section we examine some examples of how the micro-level of deliberative processes are reflected in macro-level linguistic behaviour.

Planning

Automatic processing is stimulus driven and well suited to mapping an input onto a unique output. Therefore much of word recognition and comprehension proceeds without any need for decision making or planning; the goal of comprehension is to retrieve the meaning of the speaker or writer. There are of course occasions where the output of the comprehension system is so ambiguous, incomprehensible or shocking that the comprehender has to stop and reflect upon that output, but these occasions are rare.

We have very little choice in comprehension. We have no control over the input, and only rarely will we have a choice in how we interpret that input (and when this happens a misunderstanding results). Language production is a different matter. Although there are many automatic processes in production (e.g. lexicalisation), and production is often relatively fast and efficient, there is a great deal of choice in production, from deciding what to say, choosing an appropriate syntactic frame, and choosing between synonyms. Planning means prioritising, and of necessity involves the CE. Decision making and planning take time, place a heavy load on working memory, and are needed when there is either a choice of output or when a new schema has to be created. Indeed, speaking is all about choice; we have complete control over what we say - and over what we don't. Even staying silent involves a choice. The degree of deliberation over what we choose to say varies - in a heated discussion we may immediately regret what we've just said.

Manipulation

Metalinguistic knowledge is what we know about our language and language skills, and the processes that access and use this knowledge are called metalinguistic processes. Metalinguistic processes form one component of our more general metacognitive abilities that enable us to monitor, regulate, and manipulate our own cognitive abilities (Karmiloff-Smith et al., 1996). They enable us to reflect upon our language, and make decisions about our linguistic output. Metalinguistic processing involves retrieving information, storing it in working memory, and manipulating it in some way. It operates at a number of levels of processing, from phonology to meaning. Examples include grammaticality judgement, learning to read, learning a second language, making certain inferences in comprehension, monitoring that the listener understands what we are saying in a conversation, and in understanding jokes, puns, sarcasm, and irony.

Let us consider these final examples in more detail. This role of metaknowledge in conversation is perhaps most apparent when the principle employed by cooperating speaker to make the conversation meaningful and purposeful is apparently flouted, and speakers have to make conversational implicatures (Grice, 1975). For example, if Lesley asks Trevor "Do you like my new hair style?", and Trevor pauses and replies discreetly "I think I'll go and put the kettle on", Lesley will use her knowledge of pragmatics (particularly using the maxim of relevance) to draw the obvious conclusion. At the more micro-level of textual comprehension, all elaborative inferences that go beyond the meaning of the text involve accessing semantic and pragmatic knowledge and using that knowledge to "fill in" gaps, either immediately or during some later recall (e.g. Barr, 2008; Bott & Noveck, 2004; Bonnefon, Feeney, Villejoubert, 2009; Brehenya, Katsos, & Williams, 2006; Dooling & Christiaansen, 1977; Garrod & Terras, 2000; Harley, 2008; Sulin & Dooling, 1974).

Sarcasm, humour, irony and other figurative language all require metalinguistic ability (Cacciari, & Tabossi, 1988; Gibbs, 1986a,b). Gibbs (1999) argued that comprehension of sarcasm is achieved through complex metarepresentational reasoning. If someone says "it's freezing in this room" in a room that has a temperature of 90 F, the context of the room would allow you to derive a non-literal meaning from the person's statement. In general many indirect speech acts (Searle, 1969) may need deliberative processing to be understood.

Metalinguistic processing involves the retrieval of knowledge about language, holding it in working memory, and manipulating or commenting on that knowledge, although different types of metalinguistic process use these components to differing extents. It makes heavy demands on the CE and therefore involves the frontal lobes. Metalinguistic processes are characterised by pauses when the person reflects upon their language, accesses, or uses knowledge about the form of language. Metalinguistic processes will therefore take significant time to execute and should therefore be particularly sensitive to time-shortage.

Strategy

People can make use of different strategies when tackling some language tasks. Strategies are clearly deliberative, involving an element of choice and requiring resources. Perhaps the best example of strategic processing is that of the speed-error trade-off, where people can choose to emphasise speed over accuracy, or vice versa; another example is choosing to emphasise one reading route over another (Monsell et al., 1992; Kinoshita & Lupker, 2007). Strategic effects are widespread in word recognition and are particularly prevalent when participants notice relationships between stimuli and modify their responses on the basis of these dependencies (e.g. cue validity in semantic priming studies – see Tweedy, Lapinski, & Schvaneveldt, 1977).

Strategic processing involves making decisions. Different schemata and plans are activated because different – perhaps competing, as in speed-error trade-off designs – goals need to be satisfied. Hence strategies will be affected by the participants' beliefs about the task demands, their abilities to note dependencies in the stimuli, and the instructions that they have been given. Strategic processes should therefore be sensitive to stimulus dependencies and the effects of instruction.

Control

Controlling conversation involves many aspects of high-level cognition. Indeed, effective conversation depends greatly on the effective use of deliberative processes. The aspects of conversation that use deliberative processing include deciding whether to initiate or close a conversation, planning what to say, using strategies (such as deciding when to switch topics), updating information and relating it to what has gone before (called the given-new contract; see Clark & Haviland, 1977), and metalinguistic skills (knowing how to pitch your conversation and make appropriate lexical choices). Indeed, deliberative processes permeate most aspects of pragmatics, and are essential for the speaker to be able to use any kind of figurative or non-literal language, and for the listener (or, indeed, reader) to be able to decode it by drawing inferences. Our edifice of elaborative inferences, conversational implicatures and Gricean maxims is built upon deliberative processing (see Clark, 1996, and Harley, 2008, for reviews). As we shall see, impairment of the ability to use non-literal language is a consequence of damage to the areas of the brain that support these processes.

Suppression

Inhibition and suppression are important mechanisms whereby we exclude something from attention. Inhibition plays a vital role in cognition, and has long been known to be an important component of word recognition; Neely (1991) argued that semantic priming in visual word recognition has a fast-acting, facilitatory, automatic component, and a slow-acting, inhibitory, attentional component that takes time to become available, and which reflects the participant's conscious expectations about what is happening in each trial. In priming tasks such as Neely's, inhibitory processes are particularly sensitive to the time interval between the prime and the target, called the stimulus-onset asynchrony (SOA), with inhibition taking time to build up; hence we only see expectancy-based inhibition at longer SOAs. Inhibitory processes are only manifest at longer SOAs; they are also sensitive to the person's conscious expectations and emerge over time.

Suppression is an important part of comprehension (Gernsbacher, 1997): less able readers and older adults are less efficient at suppressing irrelevant information when reading. Gernsbacher and Faust (1991) compared the inhibitory processing abilities of more versus less skilled university-aged comprehenders. They required participants to read a series of sentences. The critical sentences contained a homophone (e.g. “he had lots of patients”), and were followed by test words that were related to the other form of the homophone (e.g. “calm’). They found that both the skilled and less skilled comprehenders rejected the test word as being related more quickly when it followed a sentence that did not contain a homophone (e.g. “He had lots of students”). Both participant groups therefore experienced interference from the activation of inappropriate forms of the homophone. However, when the presentation of the test words was delayed by 1000 milliseconds, the more skilled comprehenders were better than the less-skilled comprehenders at suppressing the inappropriate homophone. Gernsbacher and Faust concluded that skilled readers are faster at suppressing inappropriate meanings than less skilled readers. Suppression has both costs and benefits: Gernsbacher (1997) proposed that when participants read a sentence that contains a homonym they suppress the meaning that is not implied by the sentence, and if they are later presented with a sentence that implies the previously suppressed meaning, a cost is incurred. This cost is transitory but the benefits of enhancing a relevant meaning last much longer.

Gernsbacher (1997) argued that inhibition is distinctive from suppression. Suppression is the attenuation or reduction of unwanted activation while inhibition is the blocking of unwanted activation. Gernsbacher uses the analogy of a candle, suggesting if we see lighting the candle as activation of a thought or action, then wetting the wick would be analogous to inhibition, while blowing out the ignited flame is analogous to suppression. Suppression can only occur once the information has been activated, while inhibition prevents activation in the first place.

The involvement of working memory in language

By definition, all deliberative processes involve resources of some kind. There are several different accounts of how language processes make use of short-term memory. The differences between these approaches are not important for our discussion, but it is necessary to explore the way in which deliberative processing is related to transfer in and out of short-term memory, and some of the consequences of difficulties with this transfer.

Norman and Shallice (1986) identified two types of control process: a *supervisory attentional system* and *contention scheduling*. The Supervisory Attentional System (SAS) is responsible for decision making, responding in novel situations, and solving problems. Contention scheduling is an automatic conflict resolution process for selecting among competing organised plans (called *schemas*) on the basis of current priorities and environmental information. The SAS is based in the frontal lobes of the brain (and corresponds to the CE). The SAS is involved with at least three types of cognitive activity (Burgess & Shallice, 1996; Shallice & Burgess, 1996): when we need to construct a new schema to control behaviour in a novel situation; when we have to implement that schema to achieve our goal; and in monitoring the new schema to make sure that it does its job. Imaging suggests that top-down activation of schemata and strategy selection occur in the left dorso-lateral prefrontal cortex; specification of which memories need to be retrieved in the right ventrolateral prefrontal cortex; monitoring and checking in the right dorso-lateral prefrontal cortex; and setting up intentions in Area 10 (Shallice, 2002).

The best known account of the structure and function of short-term memory storage is Baddeley's Working Memory model (see Baddeley, 2007, for a recent description) which provides an account of temporary storage and how it relates to long-term storage. The important point about Working Memory (WM) is that the unitary structure conceptualised by earlier memory researchers is replaced with a multicomponent structure. A Central Executive (CE) is the centralised attentional control system which controls two subsidiary limited-capacity storage systems, the phonological loop and visual-spatial sketchpad. Baddeley later added an episodic buffer to the model, but it is the limited-capacity speech-based phonological loop (used among other things for articulatory rehearsal) and the attentional control system CE that concern us most here.

Although the phonological loop is involved in helping us learn a new language, it must also play some central role in controlling action (Baddeley, 2003): the phonological loop contains the most active phonological representations at any time, and acts as a buffer containing output prepared for production. Phonological activation is just the tip of the linguistic iceberg, however. During speech production phonological activation is supported by semantic activation. R. Martin, Lesch, and Bartha (1999) proposed that there are buffers for phonological, lexical and semantic processing containing the items in long-term memory that have been most recently activated, either in comprehension or production. The activation of phonological strings is supported by semantic and lexical representations. As in the case of rehearsal, this influence is most prominent for items at the beginning of the string (Brown, Preece, & Hulme, 2000; Vousden, Brown, & Harley, 2000). Damage to lexical and semantic representations leads to reduced span, which especially affects the recall of items at the beginning of the string (Martin & Saffran, 1990, 1997).

The idea that a central memory resource is used in language comprehension is known as the Capacity Theory (Just & Carpenter, 1992). Some researchers explain syntactic comprehension deficits such as agrammatism in terms of a reduction in working memory capacity (probably the episodic buffer in Baddeley’s terms; see Blackwell & Bates, 1995; Miyake, Carpenter, & Just, 1994). On the other hand, in disorders such as Alzheimer’s disease, drastic reduction in short-term memory span is not accompanied by any obvious syntactic impairment, and although some patients with short-term memory impairments have syntactic problems, crucially not all do (e.g. Butterworth, Campbell, & Howard, 1986). Generally, whether or not language processing that involves short-term storage necessitates shared central resources or a dedicated system remains controversial: the evidence suggests that parsing involves a specific syntactic processing resource or buffer and does not draw on general working memory (Caplan & Waters, 1999; Waters & Caplan, 2005). Higher-level processes such as integration and making elaborative inferences, however, almost certainly employ working memory.

Working memory has an important role in normal adult speech production. We have already seen how working memory is used in planning and maintaining conversations, but working memory may also be involved in causing some types of speech error. Most slips of the tongue (e.g. sound errors and word substitutions) arise from faulty automatic processing. However, some arise from the intrusion of working memory contents into the output phonological buffer; examples include the competing plan and particularly the intruding thought errors of Harley (1984). The extent of the involvement of deliberative processes in the origin of speech errors is uncertain – apart from perhaps detailed interviewing of speakers at the time they make their error, how could we distinguish “automatic” errors from “non-automatic” errors? The distinction is important because these two types of errors might be subject to different constraints: non-automatic errors might involve the intruding word being activated for much longer than usual (e.g. if present in the environment or active in working memory). Note that the same might also be true of the errors made by aphasic speakers, and error types other than word substitutions (particularly blends).

The neuroscience of deliberative processing

In this section we show the extent to which deliberative processes can be localised by examining neuroimaging studies, studies of patients with brain lesions and neurodegenerative disorders such as Parkinson's Disease. We demonstrate that the fronto-striate loop (a system involving the sub-cortical structures of the basal ganglia, thalamus and the frontal cortex, specifically the prefrontal cortex and anterior cingulate; see Figure 1) is particularly important for deliberative processes. Poor working memory may therefore follow from damage to any part of the loop, whether it is at the level of the basal ganglia or the frontal cortex (Gabrieli, 1998). Language functions relying on the integrity of the fronto-striate loop will be affected when this system is disturbed by disease or injury.

Evidence from neuroimaging

Components of executive functions can be located in several regions of the frontal area (e.g. Collette & Van der Linden, 2002; Morris, 1996; Ridderinkhof, van den Wildenberg, Segalowitz & Carter, 2004). Tasks such as maintenance and monitoring involve the left-frontal gyrus, and the middle and superior frontal gyri are particularly important to normal processing when the pressure on working memory is increased (Rympa, Prabhakaran, Desmond, Glover & Gabrieli, 1999). Passingham and Sakai (2004) found that planning that makes use of sensory information involves the anterior mid-frontal gyrus. Imaging techniques have also localised the CE in three regions of the prefrontal cortex: the anterior cingulate, the orbito-frontal, and the dorso-lateral regions (Posner & Peterson, 1990). Each of these regions serve different aspects of attention (Fuster, 2002). The anterior cingulate is involved in the conscious control of vocalisation (McNamara & Durso, 2000) and is required for controlling and directing our attention and actions (Casey, Trainor, Giedd, Vauss, Vaituzis, 1997; Goldman-Rakic, 1987; Posner, Peterson, Fox & Raichle, 1988; Smith & Jonides, 1999). The orbito-frontal region is directly involved in controlling, and also correcting and reward and punishment-related behaviours (Rolls, 2004). Orbito-frontal damage also results in perseveration in both rats (Chudasama et al., 2003; Kim, & Ragozzino, 2005) and humans (Graham et al., 2009; Leeson et al., 2009) during reverse-learning tasks. The dorso-lateral region is involved in the allocation of resources and the planning, maintenance and monitoring of goal-related information in working memory, such as during the self-ordered selection of visually presented stimuli (Brown, Soliveri & Jahanshahi, 1998; D'Esposito, Detre, Alsop, Atlas & Grossman, 1995; Jahanshahi & Dirnberger, 1999; Petrides, 2000; Petrides & Milners, 2000).

Evidence from lesion studies

Language depends on many other regions of the brain in addition to the "traditional" language centres of the left cortex, such as Broca's and Wernicke's regions. It is well known that damage to frontal systems leads to a range of impairments to planning and control across a range of cognitive tasks, resulting in what is known as the *dysexecutive syndrome* (see Banich, 2004, and Gazzaniga, Ivry, & Mangun, 2002 for reviews).

Lesions that disturb the normal functioning of the fronto-striate loop disrupt deliberative processes. Patients with frontal lesions show language problems in addition to dysexecutive syndrome and working memory impairments, particularly for language tasks requiring awareness, organisation and monitoring. One of the most well documented impairments resulting from frontal damage is transcortical motor aphasia, which results from posterior lateral frontal damage (Mega, Alexander, Cummings & Benson, 2000).

Transcortical motor aphasia is exemplified by difficulty in initiating speech, with utterances typically being very short and production very effortful, while comprehension and repetition are relatively intact.

Thompson-Schill, D'Esposito, Aguirre, and Farah (1997) showed that patients with damage to the left inferior pre-frontal cortex were unable to generate verbs to go with nouns that are associated with many plausible verbs (e.g. "rope" is associated with verbs such as "tie", "twirl", "twist"), but could generate verbs to go with nouns with only one highly frequent plausible associated (e.g. "scissors" is only really associated with "cut"). These patients seem unable to inhibit competing alternatives.

Impairments of the sequential organisation of language have been associated with left dorso-lateral lesions (Stuss & Benson, 1986). Radanovic and Scaff (2003) found that damage to the left-frontal periventricular white matter projection, left putamen, caudate nucleus and internal capsule, result in poor comprehension and naming difficulties, particularly poor control of language resulting in an increase in paraphasias. Lesions of the right putamen, anterior limb of the internal capsule and the posterior periventricular white matter projections are associated with the comprehension and elaboration of narratives. The caudate nucleus is bilaterally small in at least some members of the KE family as a result of a mutation of the FOXP2 gene, and is associated with poor speech production abilities, poor grammatical comprehension, and impaired phonological skills (Lai, Fisher, Hurst, Vargha-Khadem, & Monaco, 2001; Lieberman, 2006; MacDermot et al., 2005; Watkins, Dronkers, & Vargha-Khadem, 2002; Vargha-Khadem, Gadian, Copp, A., & Mishkin, 2005). Striatal and cerebellar dysfunction, associated with FOXP2, leads to motor-skill learning deficits in mice (Groszer, et al., 2008) and auditory-guided vocal motor learning deficits in birds (Haesler et al., 2007).

Clearly the circuitry connections between the basal ganglia, the thalamus and the prefrontal cortex are particularly important for controlling language.

Individuals with aphasia resulting from damage to the thalamus have relatively fluent speech, relatively unimpaired comprehension, and preserved repetition, but show an increase in word substitutions, perseveration and impaired spontaneous speech (Crosson, 1984). The thalamus is involved with semantic monitoring (Cappa & Vignolo, 1979; Crosson, 1984), activating cortical language systems (Hornstein, Chung & Brenner, 1978), and regulating access to language information stores (Botez & Barbeau, 1971) - all aspects of controlling language.

Regions of the right-frontal lobes are particularly involved with understanding some forms of indirect speech, especially humour, irony, and sarcasm. Patients with prefrontal damage are particularly impaired at understanding sarcasm, with damage to the right ventromedial prefrontal regions leading to the most profound impairment (Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005). The role of the right hemisphere in understanding jokes is well known (Brown et al., 2005; Brownell, Potter, Bihrle, & Gardner, 1986; Brownell, Michel, Powelson, & Gardner, 1988; Coulson et al., 2001; Coulson, & Williams, 2005; Heath & Blonder, 2005; Shammi & Stuss, 1991) furthermore this area has a role in certain types of inference (Beeman, 1993; Champagne-Lavau, & Joanette, 2009; MacDonald, 1999).

The integration of deliberative processing

The fronto-striate loop has to connect to the traditional language centres of the left hemisphere. Neural pathways run to and from the frontal cortex to the basal ganglia and the thalamus. The caudate nucleus receives information from language sites within the frontal cortex and relays that information to other areas of the basal ganglia such as the internal capsule. The information sent to the caudate nucleus is therefore uni-directional. Information is also sent to the thalamus by the caudate nucleus. The thalamus however forms a bi-directional pathway to the frontal cortex specifically to areas such as Broca's area. Language functions are therefore dependent on the bi-directional flow of information within the loop.

Whereas automatic language processing is strongly lateralised, deliberative processes appear to be bilateral. We argue that the fronto-striate loop is the host for the processes that control language, and that damage to the loop will lead to language difficulties. Furthermore, failure of the loop to develop normally will lead to particular types of developmental language disorder.

Deliberative processes across the lifespan

Deliberative processes play an essential role in language acquisition and their decline is one of the major causes of language impairment in late adulthood. Here we review the literature on deliberative processes in childhood and old age. Examination of the development of deliberative processes provides a framework for considering the impact of neurodegenerative processes much later in life. We conclude that there is an inverse relationship between the development and the degeneration of high-level linguistic functions.

The development of the neural substrate of deliberative processes

Neuroimaging during the neonatal period shows that the most significant metabolic activity occurs in the primary sensorimotor area. By 4 weeks of age we can see a slight increase in activation in the parietal cortex, and by 12 weeks there is increased activation in the parietal, temporal and occipital cortices; the frontal cortex shows less evidence of maturation during this period (Chugani, Phelps & Mazziota, 1994). Between 15 and 24 months the frontal cortex increases its connections with other cortical regions; importantly there is an increase in the strength of the connections between the hypothalamus, thalamus, basal ganglia and the cerebellum (Herschkowitz, 2000). The frontal cortex resembles that of an adult by 12 months (Chugani et al., 1994; Diamond, 2002), and reaches full maturity at puberty (Orzhekhovskaya, 1981; Stuss, 1992).

The basal ganglia and the thalamus mature much earlier than the cortical regions. The thalamus shows signs of activation five days after birth (Chugani et al., 1994), while the striatum shows clear signs of maturation before the child is born (Voorn, Kalsbeek, Jorritsma-Byham & Groenewegen, 1988). Fronto-striatal connections begin to develop from the first week after birth, and are adult-like at 4 weeks (Anonopoulous, Dori, Dinopouloos, Chioletti & Parnavelas, 2001; Sharpe & Tepper, 1998).

The cingulate gyrus is particularly vulnerable to teratogens *in utero*. Studies show that prenatal exposure to alcohol (Archibald et al., 2001; Cortese et al., 2006; see Spadonia, McGeea, Fryera, & Riley, 2007, for a review) and cocaine (Chang et al., 2004; Dixon, & Bejar, 1989; Frank, McCarten, Cabral, Levenson, & Zuckerman, 1994) result in anatomical and neurochemical changes to the dopaminergic system, and in particular to the caudate nucleus. In preterm infants, hypoxic-ischemic injury can also result in damage to the dorso-lateral caudate nucleus (Nosarti, Allin, Fangou, Rifkin & Murray, 2005). Disturbances to the frontal cortex and the basal ganglia during foetal and postnatal development have detrimental effects on normal cognitive and linguistic development. For example, Foetal Alchohol Syndrome (FAS) is associated with poor working memory and other cognitive deficits specific to frontal-lobe functioning, such as planning and reasoning (Jacobson, Jacobson, Sokol, Martier, & Ager, 1993; Mattson, & Riley, 1998; Rasmussen, 2005). There is also evidence of language delay and difficulties with articulation in children suffering from FAS (Iosub, Fuchs, Bingol, & Gromisch, 1981; McGee, Bjorkquist, Riley & Mattson, 2009; Steinhausen, Nestler, & Spohr, 1982). Children born preterm also present with similar developmental difficulties. For example, preterm infants who have suffered periventricular injury are at greater risk of suffering from general cognitive delay (Woodward, Anderson, Austin, Howard, & Inder, 2006) and more specifically, deficits in spatial memory and executive function (Taylor, Minich, Bangert, Filipek, & Hack 2004).

The maturation of the dorso-lateral prefrontal cortex plays an important role in the development of executive processes during infancy (Diamond, 2000). Dopamine is essential for the normal functioning and development of the dorso-lateral prefrontal cortex, and enhancement in cognitive function relies on effective dopaminergic projections to this region. Abnormal development of these projections will result in conditions that show executive impairments. For example, phenylketonuria (PKU) disrupts the levels of dopamine outside the dorso-lateral prefrontal cortex, and hence these children often suffer from executive impairments such as attentional control, problem solving, inhibition and set-shifting (Diamond, 2000).

What role do deliberative processes play in language acquisition? Children learn to hold conversations in an orderly way; they learn how to make inferences; they acquire knowledge about the nature of language; they develop linguistic strategies; they learn when to inhibit competing alternatives; and they learn how to plan. In short, they learn metalanguage. Indeed, if we adopt Vygotsky's (1934) viewpoint that early egocentric speech is internal speech externalised, we can literally "hear" the early central executive in action. It is likely that deliberative processing is involved in all aspects of language acquisition, but it is beyond the scope of this paper to go into more detail.

Deliberative processing across the lifespan

Spoken language acquisition is a more "natural" process than written language learning, as shown by the greater number of developmental difficulties in learning to read. Written language development probably involves even more deliberative processes than does spoken language. Acquisition of the alphabetic principle and the development of phonological awareness clearly involve reflection and manipulation, and are heavily dependent on deliberative processing (see Ehri 2005, Goswami, 2008, for recent reviews).

Our position, then, is that central processes play an essential role in many aspects of language development. A more extreme version of this viewpoint is the Cognition Hypothesis, which states that general cognitive processes occupy the driving seat in language development (see Harley, 2008, for a review). To acquire language normally, the child must be able to use deliberative processes, and for that to be possible the fronto-striate loop must be developed and functioning. We now examine what happens when things go wrong with this development.

Evidence from developmental disorders

The existence of developmental language-specific disorders is now well established. While some specific disorders appear to be linked to genetic abnormalities that result in impairments to phonology or syntax (e.g. Gopnik & Crago, 1991; Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995), a number of other more general developmental disorders result in disturbed language acquisition. We argue that at least some of these difficulties arise because of impairments to deliberative processes resulting from the abnormal development of the fronto-striate loop. Hence we should observe unusual language use in developmental cognitive deficits not traditionally thought of as being developmental linguistic disorders.

Children with autism may show language impairments. In particular, the absence of a theory of mind (TOM) leads to difficulty in learning words. “Theory of mind” is a complex skill, relying on several precursors such as joint attention, gaze processing, distinguishing between oneself and others, representing goal-directed actions, and representing actions (Astington & Dack, 2008; Charman et al., 2000; Gomez, 2005; Meltzoff, 1999; Sebanz, Knoblich, Stumpf, & Prinz, 2005). There are significant differences between the brains of autistic and non-autistic individuals: fronto-striatal pathways are anatomically and functionally different in children with autism, with the abnormal development of the caudate nucleus and delayed maturation of the frontal cortex being particularly prominent (Abelle et al., 1999; Carper & Courchesne, 2005; Courchesne, 1997; Damasio & Maurer, 1978; Peterson, 1995; Schmitz, Rubia, Daly, Smith, Williams & Murphy, 2006; Sears, Vest, Mohamed, Bailey, Ranson et al., 1999; Zilbovicius, Garreau, Samson, Remy, Berthelemy et al., 1995). Disturbances of the fronto-striate regions result in executive function impairments (Hill, 2004), and people with autism perform poorly on tasks such as planning (Ozonoff & Jensen, 1999; Ozonoff & McEvoy, 1994), set-shifting (Rumsey, 1985; Rumsey & Hamburger, 1988), inhibition (Hughes & Russell, 1993) and verbal fluency (Minshew, Goldstein, Muenz & Payton, 1992; Rumsey & Hamburger, 1988).

Impairment of deliberative processing leads to several linguistic disturbances. Children with autism often fail to make appropriate inferences (Mason, Williams, Kana, Minshew, & Just, 2008; Oznoff & Miller, 1996; Preissler & Carey, 2005) and their knowledge of the nature of language is impoverished such as they fail to understand that language can be used to convey humour (Oznoff & Miller, 1996) or irony (Happé, 1993). Metalinguistic skills are attained in part through intra-verbal learning (DeBaryshe & Whitehurst, 1986; Marazita & Merriman, 2004), and therefore high-level communication skills develop by engaging in two-way conversations, something that autistic children do not usually do. There is clear evidence of impaired metalinguistic knowledge in children with autism. Autistic children have poor comprehension and pragmatic abilities (Tager-Flusberg, 1981). Although comprehension might improve with age, pragmatic deficits such as turn-taking, maintaining the topic of conversation, and being aware of what an other person intends, can all endure into old age in autism (Rapin & Dunn, 2003).

If self-monitoring is impaired, people will have difficulty keeping track of what they have said, making it very difficult for them to keep the topic of conversation in mind (Hughes, 1996; Russell & Jarrold, 1998, 1999). Autistic individuals frequently forget the topic of conversation or fail to notice the irrelevance or inappropriateness of what they say.

Finally, Happé (1993) found that autistic children who had no TOM were unable to comprehend figurative speech, metaphors or irony. Autistic children with second-order TOM, as measured by the TOM battery, were able to understand metaphors but performed less well on tests of irony, suggesting that the use and understanding of irony require a higher level of language processing than the use and understanding of metaphorical language. Happé explained these findings in terms of Relevance Theory, suggesting that irony requires some level of meta-representation: to understand irony we must go beyond the surface-level interpretation of an utterance or a statement, and consider the interlocutor's attitudes, beliefs and intentions. An autistic child with no TOM is unaware that other people have attitudes, beliefs and intentions.

Attention Deficit/Hyperactivity Disorder (ADHD) shows some similarities with autism. Individuals with ADHD have difficulty with tasks requiring sustained attention and inhibitory processing (Ozonoff & Jensen, 1999; Tsuchiya, Oki, Yahara, & Fujieda, 2005). ADHD has been associated with a disturbance of frontal-lobe maturation resulting from disturbances to the striatum during prenatal development (Di Michele, Prichep, John & Chabot, 2005; Toft, 1999). Children with ADHD have disturbances of working memory (Cohen, Vallance, Barwick, Im, Menna et al., 2000; Jonsdottir, Bouma, Sergeant & Scherder, 2005), executive processing (Barkley, 1997; Ozonoff & Jensen, 1999; Pennington & Ozonoff, 1996; Tsuchiya et al., 2005), and attentional processing (Hurks et al., 2004). They have more difficulty organising their speech and have more difficulties with pragmatics than learning disabled and typically developing children (Barkley, 1998). They also have a tendency to be more loquacious. When asked to speak in accordance with a specific set of demands their speech becomes dysfluent (Barkley, Cunningham & Karlsson, 1983; Barkley, DuPaul, & McMurray, 1990). Barkley (1998) concluded that the difference between everyday conversation and speech during confrontation tasks reflects the impairment of higher-level executive processing.

Like children with autism, children with ADHD have more difficulty with pragmatics than they do with other aspects of language. There is an overlap in the types of pragmatic difficulties faced by ADHD and autistic children, but children with ADHD do not suffer from TOM problems. We note that autism is associated with more severe frontal pathology.

Normal ageing

It is well known that language use changes with age, with production and particularly naming particularly prone to disturbance, while comprehension and parsing are generally relatively well preserved (e.g. Burke & MacKay, 1997; Burke & Shafto, 2004).

Age-related cognitive deficits have consistently been linked to deterioration of the frontal lobes, particularly to the fronto-striate loop. We know that there are changes to the frontal regions in late adulthood (Paul et al., 2009; Zimmerman et al., 2007), particularly to the dorso-lateral prefrontal cortex (Band, Ridderinkhof & Segalowitz, 2002; Hedden & Gabrieli, 2004; West, 1996). Cummings and Benson (1983) claim that comparable patterns of change between normal ageing and degenerative diseases such as Parkinson's disease (PD) and Alzheimer's disease (AD) imply that frontal lobe disturbance is probably the principal cause of cognitive impairment in older adults. It should be noted that although there is some overlap between the neuropathological changes seen in normal ageing and those of neurodegenerative diseases, there are also some important differences. For example, we observe a decline in the concentration of N-acetylaspartate (NAA) in the grey matter in Alzheimer's disease evidences but not normal ageing (Pfefferbaum, 1999a; 1999b). In the normally ageing brain we see little evidence of senile plaques until much later in the lifespan and neurofibrillary tangles are restricted to the anterior olfactory nucleus, the parahippocampal gyrus and the hippocampus, and in contrast to Alzheimer's disease are rarely found in the neocortex (Price Davis, Morris, & White, 2001). In the AD brain, atrophy is much more global (Brack, Brack & Bohl, 1993) and results in more volume loss than in the normally ageing brain (Guo et al., in press; Salat et al., 2009).

Although naming difficulties are a prominent feature of normal ageing, on the whole automatic language functions remain intact while deliberative language functions are impaired. Kemper (1986) found that people aged between 50 and 60 years used simple syntactic structures effectively, while people between 70 and 80 years made errors such as omitting relative pronouns, using some past tense inflections incorrectly, and failing to use necessary articles and possessive markers. The older participants avoided syntactic structures that place greater demands on working memory, such as centre-embedded and left-branching structures. She also found the older participants were poor at repeating and correcting syntactic structures; their performance declined considerably when asked to repeat long sentences with embedded clauses such as “What I took out of the oven interested my grandchildren”. Kemper concluded that these deficits resulted from poor working memory. The ageing literature clearly demonstrates that a decline in working memory is associated with a subsequent decline in the production of syntactically complex sentences (see Emery, 1986; Kemper 1990, 1992; Kemper, Kynette, Rash, Sprott, & O’Brien, 1989; Kemper, & Liu, 2007; Kemper, Rash, Kynette, & Norman, 1990; Kemper, Thompson, & Marquis, 2001).

This pattern suggests that those language functions that develop last during childhood will be the most affected in later life (see de Bot & Weltens, 1991; Kemper, 1992; 1997). What is the mechanism for this pattern of decline? Within the ageing literature a decline in processing speed seems to explain many of the cognitive impairments observed in older adults (Salthouse, 1996). However, Salthouse (1991) argues that working memory also plays an important role in age-related decline, and Brigman and Cherry (2002) claimed that cognitive slowing and poor working memory make it more difficult for older adults to achieve automaticity. A reduction of working memory capacity in older adults might result in intrusions of irrelevant information and a decline in efficient processing (Baddeley, 1986; Craik, 1977; Emery, Hale and Myerson, 2008; Hasher & Zacks, 1988; Zanto, Toy, & Gazzaley, 2010). Hasher and Zacks (1988) also argued that poor working memory performance was responsible for inhibitory processing deficits. However, we should also note that although the literature clearly demonstrates inhibitory processing deficits in older adults, inhibition appears to remain relatively spared from age-related pathology (Borella, Carretti, & De Beni, 2008) particularly when compared to other working memory functions such as speed of processing (Salthouse & Meinz, 1995).

Deliberative processing across the lifespan

We have noted that failure to inhibit has consequences for language in laboratory settings. Inhibitory deficits, as we might therefore expect, also lead to difficulties in everyday conversational settings. An inability to suppress competing responses and to remove irrelevant information from short-term memory (Arbuckle & Gold, 1993) can lead to the intrusion of inappropriate, repetitive, or irrelevant material – the so-called “loquacious” character of speech in late adulthood. Alternatively, off-target speech may be a consequence of the different communicative goals that develop with age (James et al., 1998).

If normal ageing particularly affects deliberative processes, then neurological conditions such as Parkinson’s disease and probable Alzheimer’s disease that can be said to accelerate the ageing process should result in even greater linguistic processing difficulties.

Deliberative processing and Parkinson’s Disease

The depletion of dopamine in the substantia nigra in PD disrupts the pathways between the subcortical structures and the frontal cortex (Côté & Crutcher, 1991), and leads to an over-stimulation of the thalamus and an under-stimulation of the frontal cortex. This under-stimulation means there is insufficient activation of the frontal cortex to allow working memory tasks to be carried out successfully (Jaovoy-Agid & Agid, 1980). In general, because of the pattern of the connectivity of the fronto-striate loop, dopamine depletion originating in the basal ganglia will lead to impairments of executive processing in general and deliberative language processing in particular.

PD leads to a slowing of cognitive function, an impairment in retrieval when it depends on strategic search, and executive dysfunction (Dubois, Boller, Pillon, & Agid, 1991; Hirshorn, & Thompson-Schill, 2006; Ivory, Knight, Longmore & Caradoc-Davies, 1997). Although this pattern is consistent with some impairment in frontal function, not all signs of frontal damage are displayed, or are only shown to a lesser extent: for example, planning is less disrupted than in people with explicit frontal-lobe damage. It is likely that some cognitive deficits in PD arise from damage to other subcortical structures (see for example, Owen, 2004; Owen, Doyon, Dagher, Sadikot, & Evans, 1998). In a study of motor-skill learning, people with PD and people with Progressive Supranuclear Palsy (PSP), were poorer at retaining newly learned motor-skills compared to people with AD: some people with AD could retain the new skills up to 18 months after they had learned them whereas people with PD lost the skills much earlier. Although other cortical regions such as the premotor area, the supplementary motor area and the cerebellum are also involved, normal functioning of the striatum is required for the learning and retention of new skills (Mochizuki-Kawai, et al. 2004).

Although long-term memory is intact in PD, strategic memory search is impaired, and performance in short-term memory tasks is impaired if a distracting stimulus intervenes (Pillon, Deweer, Agid, & Dubois, 1993). Memory tasks such as estimates of recency and temporal ordering that require frontal regions are also impaired. People with PD perform poorly on some neuropsychological tests of frontal lobe function, such as the Wisconsin Card Sorting test, where the participant may be unable to inhibit the response of sorting according to the previous rule (e.g. they may continue to sort by colour when this is no longer appropriate). Perseveration may be the result of either an inability to inhibit a previously correct response, or an inability to commence responding with a previously incorrect response. Using a modified version of the Wisconsin task, Owen et al. (1993) found that frontal lobe patients tended to perseverate, whereas people with PD had difficulty in making responses that had previously been irrelevant and therefore incorrect. That is, they could not start doing what was wrong before. Similar behaviours are found in lexical decision tasks whereby people with PD find inhibiting irrelevant stimuli more difficult than age matched controls, resulting in an overall decline in performance, measured by an increase in errors or processing speed (Copland, Sefe, Ashley Hudson, Chenery, 2009; Marí-Beffa, Hayes, Machado, & Hindle, 2005).

The extent to which PD specifically affects language is less clear, with a suggestion of dissociation between syntactic and lexical processing. On the one hand, people with PD have difficulty with grammatical processing. The spontaneous speech of people with PD is syntactically simplified, they have some difficulties in comprehension, and they have difficulty in inflecting regular verbs (Kemmerer, 1999; Ullman, 1999; Ullman et al., 1997). Using a morphosyntactic priming task, Arnott et al. (2005) found that although PD participants could access morphosyntactic information in a similar way to age-matched controls, the information decayed much more quickly for the PD participants. They further suggested that people with PD experience problems with post-lexical integration.

Word-finding abilities of people with PD however, appear at first sight to be relatively intact. However, Matison, Mayeux, Rosen, and Fahn (1982) observed frequent instances of anomia and tip-of-the-tongue states, and suggested that some of the periods of silence in PD speech may in fact be attributable to a word-finding disorder, rather than to articulation difficulties. Semantic category fluency was impaired but phonological category fluency was not. Matison et al. located the retrieval deficit at the semantic level because the facilitation that followed semantic priming was correlated with the severity of PD. The observation that naming errors were typically semantic associates of the target further supports this hypothesis. Similarly, Gurd and Olivier (1996) suggested word finding difficulties might result from difficulty inhibiting competition between semantically related words during word retrieval. Gurd (1996; 2000) also suggests that poorer performances in people with PD results in a slowing of word-search through the lexical-semantic long-term store.

Hence there is a conflict in the literature. Some researchers argue for preserved lexical access, while others find impairment. Furthermore, the cause of the syntactic disturbance is unclear. How can these problems be resolved? Matison et al. argued that the semantic deficit arises because of a planning disturbance: the category-naming task requires the systematic, strategic search through the lexicon, and the initiation of a response. Another hypothesis is that people with PD have difficulty with rule use (Ullman, 2004; Ullman et al, 1997): Ullman et al. (1997) found that while people with PD had difficulty with regular verbs, they could successfully inflect irregular verbs (perhaps because these are stored as specific instances rather than generated by rule, although this is controversial – e.g. McClelland & Seidenberg, 2000). In addition, specific damage to the syntactic processor, an impairment of working memory, limited speed of processing, and excessive interference have all been proposed as the underlying cause of any language impairment. Some of the difficulties faced by PD sufferers (impaired strategic search, planning disturbance, the application of rules) share the characteristic that they involve deliberative language processes. We propose that while automatic language processes (e.g. aspects of lexical retrieval and parse-tree formation) are largely left intact in PD, some deliberative processes are impaired. This suggestion might go some way to explaining the heterogeneity of the observed disruption. Bastiaanse and Leenders (2009) also suggested that PD participants perform poorly on language tasks, not because of a linguistic deficit as such, but because the cognitive functions that these language tasks rely upon e.g. verbal working memory or set-shifting, are impaired in PD. In summary, we argue that a disturbance of the executive processes that deliberative language relies upon will result in the observed deficits.

The details of the neuropsychology of parsing and comprehension support this idea. Brain imaging of people with PD suggests that the anterior cingulate cortex is involved in high-level grammatical processing (Grossman, Crino, Stern, Reivich & Hurtig, 1992). Grossman et al. found an increase of blood flow in the anterior cingulate of control participants when they were asked to process grammatically complex sentences, while no such increase was found people with PD. We have seen that the anterior cingulate cortex is involved in executive functions, and recent evidence shows that in healthy adults there is a significant increase in anterior cingulate cortex dopamine transmission during executive functioning (Ko et al., 2009). Hence people with PD, who suffer from dopaminergic disturbance, should indeed be impaired on complex grammatical tasks. Event Related Potential (ERP) studies also demonstrate the importance of sub-cortical processing during sentence comprehension. Friederici, Kotz, Werheid, Hein, and von Cramon, (2003) found the integration processes that occur late in sentence comprehension and that are supported by the basal ganglia are affected in PD, while the early automatic processes, during which the input is structured on the basis of word-category information, and which are not served by the basal ganglia, remain unaffected.

Deficits in deliberative language processing lead to more widespread communicative difficulties. McNamara and Durso (2003) argued that poor communication skills in PD result in part, from a lack of self-awareness. According to them, people with PD are impaired at communication skills such as conversational appropriateness, speech acts, stylistics, gestures and prosodic skills because they lack an awareness of their deficits. They attributed the speech impairment to a disturbance of right-frontal circuit activation, the area of the brain that controls attentional and intentional responding.

Deliberative processing across the lifespan

In our own work, we have found that people with PD are impaired across the board on language tasks that heavily involve deliberative processes, and furthermore that the degree of the impairment is correlated with the severity of the disease. For example, people with PD show phonological awareness deficits in the same way as do very young children or children with literacy problems (Harley, Jessiman, & MacAndrew, 2009; Jessiman, Harley, & MacAndrew, 2007; Oliver, Harley, MacAndrew, 2009). People with PD are much less able to inhibit alternatives and competing plans, sometimes leading to unfocussed discourse. The performance of healthy older participants falls between that of healthy younger adults and the PD group, suggesting that the consequences of age-related changes to the processes that underlie deliberative ability results in a continuum of performance on language tasks, with performance determined by the state of the integrity of the fronto-striate loop.

Language processing in Alzheimer's disease

The level of severity of Alzheimer's disease (AD) affects which executive processes are lost (Baudic et al., 2006), but AD patients are particularly impaired on dual-task performance (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991; Belleville, Chertkow, & Gauthier, 2007). People with early AD are poor at dividing attention and shifting between tasks (Fernandez-Duque, & Black, (2008), whereas sustained attention is relatively intact (Johannsen, Jakobsen, Bruhn, & Gjedde, 1999).

Global degenerative illnesses affect deliberative processes because they necessarily affect all regions of the brain. Hence in addition to language-specific impairments resulting from degeneration of the language centres, we should also observe language difficulties arising from the progressive loss of deliberative processes. Harley, Jessiman, Astell and MacAndrew (2008) found that some people with probable Alzheimer's disease (AD) frequently have access to information that they appear to have lost (see also Astell & Harley, 1998, 2002). We tested a group of elderly people with moderate AD on a word definition task. They performed very poorly relative to control participants. In contrast, they could answer questions about the elements of the definition that they did not spontaneously provide. So, for example they might be unable to define a frog as anything other than an animal, they could answer forced- and open-choice questions that demonstrated that they knew it had four legs, was green, lived in the water, laid spawn and began life as a tadpole. We concluded that although our moderate AD participants have lost some semantic knowledge, on at least some occasions they do not provide information that they do still know because of a metalinguistic impairment - they no longer understand what constitutes a good definition. We related this metalinguistic impairment to a frontal-lobe deficit associated with general cortical atrophy.

Conclusion

While many agree that language is in a loose sense a special module, a great deal of language processing isn't privileged in a modular sense but arises from non-dedicated processing. We have shown that non-automatic, or *deliberative*, processing pervades and controls language development and use. Deliberative processing is essential for the normal development of both spoken and written language, and its disruption leads to abnormal acquisition, impaired language use in adults, and importantly, to most of the prominent symptoms of normal and pathological ageing. We have drawn particular attention to the role of the fronto-striate loop in language processing. The notion of deliberative processes has great explanatory power. Deliberative processing is a step in integrating language processing with a general framework of cognition, a neurobiological account of language and cognitive impairment, developmental psycholinguistics, and the neuropsychology of ageing.

Implications for therapy

Therapists should obviously be aware of the existence of deliberative language processes, and the fact that all language processing reflects a mixture of automatic and deliberative processing. We have shown that the impact of deliberative processing changes with age, and the deliberative processes are more affected by normal ageing than automatic ones. Furthermore, certain types of more global age-related pathologies will lead to great changes in deliberative language processing, affecting everyday language skills.

The good news is we think that disorders of deliberative processing might be more amenable to therapeutic intervention than disorders of automatic processing. Once the therapist is aware that a process is disrupted, it should usually be possible to devise a strategy to circumvent that deficit. Indeed, many of the treatments of automatic processing deficits in any kind of speech therapy involve the use of deliberative processing strategies. Here awareness, both on the behalf of the therapist and the patient, is the key word. As we have shown with our work on dementia, the answer can be as simple as asking the right question.

Non-linguistic executive skills have also recently become a focus for speech therapy. There is evidence that training on attentional skills in particular may in some circumstances lead to improvements in speaking and reading (e.g. Coelho, 2005; Helm-Estabrooks, 1998; Mayer & Murray, 2002). In cases of severe aphasia, only alternative modes of communication (e.g. using a computer) may prove effective. Preserved executive function (e.g. goal formulation, planning, carrying out plans, and monitoring) discriminates between patients likely to respond well to alternative modes and those likely to do less well; so much so that it has been proposed that tests of executive function should be a routine part of aphasia assessment when such treatments are to be used (Nicholas, Sinotte, & Helm-Estabrooks, 2005). In support of this idea, our own research with PD has shown that scores on routine tests of non-linguistic executive functions correlate with performance on a range of linguistic tasks (Harley et al., 2009; Oliver et al., 2009). Treatment of executive functions themselves can lead to more effective communication, even many years post-onset (Ramsberger, 2005).

In summary, deliberative processes play an essential role in using language. Although psychologists have largely restricted their investigations of language processing to automatic processes, this restriction does not always address how language is used outside the laboratory. It is time for the role of central processes in language to become an object of widespread investigation in their own right, and their importance for therapy given more prominence.

Note

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Figures

Figure 1. Schematic figure of the fronto-striate loop, showing the main structures involved and the pattern of connectivity.