Chapter 11: Language production

We know more about language comprehension than language production. Why is this so? We can control the material to be comprehended, but it is harder to constrain an individual’s production of language. A further problem in accounting for language production (shared with language comprehension) is that more than a theory of language is needed. Language production is basically a goal-directed activity, having communication as its main purpose. People speak and write to impart information, to be friendly and so on. Thus, motivational and social factors need to be considered.

The two major topics considered in this chapter are speech production and writing, with a final section on the relationship between language and thought. More is known about speech production than about writing. Nearly everyone spends more time talking than writing, and so it is of more practical use to understand the processes involved in talking. However, writing is an important skill in most societies.

Spoken and written language both have as their central function the communication of information about people and the world. However, children and adults often find writing much harder than speaking, suggesting there are major differences between the production of spoken and written language.

- Introduction

Language is a goal-directed activity having communication as its goal. Motivational and social factors need to be considered in addition to linguistic ones. There is controversy over the extent to which psychological processes involved in spoken and written language are the same or different.

The view that speaking and writing are similar receives some theoretical support. It is generally assumed that there is an initial attempt to decide on the overall meaning to be communicated, and at this stage the actual words are not considered. This is followed by the production of language, which often proceeds on a clause-by-clause basis. Gould (1978) compared dictated and written business letters and found dictation was rarely more than 35% faster than writing. Compare this with normal speech, which is more than five times faster than writing. Gould suggested planning took two-thirds of total composition time for both writing and dictation; hence there is only a moderate speed advantage for dictation.

There are several differences between speaking and writing. Written language uses longer and more complex constructions. Writers make more use of words and phrases signalling what is coming next. Prosody is important in spoken language. Four differences are:

- Speakers know who is receiving their messages.
- Speakers receive moment-by-moment feedback from the listener and adapt what they say.
- Speakers have less time to plan their language production.
- Writers have direct access to what they have produced so far.

As a consequence, spoken language is often informal and simple in structure, with information communicated rapidly. Written language is more formal, more complex and slower. Some brain-damaged patients have writing skills that are intact, despite an inability to speak (Levine et al., 1982). Other patients can speak fluently but find writing difficult (Kolb & Whishaw, 2003).

We typically speak at two to three words a second or about 150 words a minute, and this rapid speech rate fits the notion that speaking requires few processing resources. We use various strategies when talking to reduce processing demands, such as:

- preformulation
- underspecification.
Speech production involves several stages and these levels (Dell, 1986):

- syntactic
- semantic
- morphological
- phonological.

The same knowledge base and similar planning skills are used in speaking and in writing, but spoken language is typically more informal and simpler than written language. Some brain-damaged patients can speak well, although their spelling and writing are poor, and others can write accurately but can hardly speak. However, the higher-order processes involved in speaking and writing may be similar.

- **Speech planning**

  Generally we think before we speak. Lee et al. (2013) found the time to speech onset was longer when speakers produced sentences with a more complex syntactic structure. This suggests they prepared at least part of the syntactic structure of what they were about to say in advance. Planning of speech may be at the clause or phrase level. Evidence for planning at the clause level comes from speech errors. Speakers often hesitate or pause before the start of a clause (Holmes, 1988). However, speakers take longer to initiate speech when using complex initial phrases (Martin et al., 2004).

  The amount of planning preceding speech is flexible and varies according to situational demands. Ferreira and Swets (2002) found evidence that participants fully planned their responses before speaking. However, when time was limited, some planning occurred before speaking, and additional planning occurred during speaking. Wagner et al. (2010) suggest the amount of planning involved was determined by cognitive load, complexity of the sentence and speed of speech.

  There has been controversy over how much forward planning of speech occurs. In general, when speakers are free from constraints over what to say and when to say it, speech planning can be fairly extensive, including entire phrases or clauses. However, when the task is more artificial or speakers are under time pressure, planning is more limited. Further research is needed to clarify whether these findings generalise to more naturalistic situations, and to assess the precise extent of forward planning.

- **Speech errors**

  It has been estimated that the average person makes a speech error every 500 sentences (Vigliocco & Hartsuiker, 2002). This is highly accurate, but errors can be used to aid our understanding. The speech errors even of brain-damaged patients are generally similar to the correct words (Dell et al., 2014).

  There are several types of speech error:

  - *Spoonerisms*, which occur when the initial letter or letters of two words are switched.
  - *Freudian slips*, which supposedly reveal the speaker’s true desires.
  - *Semantic substitutions*, when the correct word is replaced with one of a similar meaning.
  - *Morpheme-exchange errors*, where inflections and suffixes remain in the correct place, but are attached to the wrong words.
  - *Number-agreement errors*, where singular verbs are used with plural subjects and vice versa.

  Motley (1980) studied Freudian slips and found the number of spoonerisms was greater when the situation produced sexual arousal. According to Haskell and MacDonald (2003), we need to use considerable processing resources to avoid number-agreement errors.

**WEBLINK:** [Fun spoonerisms](https://example.com/_fun_spoonerisms)
In his perceptual loop theory, Levelt (1983) argued that speakers detect their own speech errors by listening to themselves and discovering that what they say sometimes differs from what they intended. Nozari et al. (2011) favoured an alternative conflict-based theoretical account. They argued that error detection relies on information generated by the speech production system itself rather than the comprehension system.

Huettig and Hartsuiker (2010) found speakers monitored their overt rather than inner speech. There is practically no correlation between comprehension ability and error-detection performance. In contrast, speech-production ability predicts error detection (Nozari et al., 2011). These results fit with the conflict-based theoretical account. Nooteboom and Quené (2013b) found errors detected early by speakers had high perceptual clarity. This finding suggests conflict during speech planning and production may not account for all speech errors.

Speech errors, many of which involve problems with selecting the correct word, can shed light on the processes involved in speech production. Common types of speech errors are spoonerisms, Freudian slips, semantic substitution errors, morpheme-exchange errors and number-agreement errors.

- Theories of speech production

Dell (1986) proposed a spreading-activation theory based on connectionist principles. A representation is formed at each level. It is assumed the nodes within a network vary in activation or energy. When a node or word is activated, activation or energy spreads from it to other related nodes or words. Processing during speech planning occurs at the same time at all levels; it is parallel and interactive. Categorical rules occur at each level and are constraints on categories and combinations that are acceptable. There is a lexicon (dictionary) in the form of a constructionist network. Insertion rules select the items for inclusion in the representation. According to the theory, speech errors occur because an incorrect item is sometimes more activated than the correct one. The notion that numerous nodes are activated at the same time increases the risk of speech errors.

The mixed-error effect occurs when a spoken word is both semantically and phonetically related to the correct word. This error suggests semantic and phonological factors can both influence word selection at the same time (Levelt et al., 1999). Speech errors tend to consist of actual words rather than non-words (the lexical bias effect). According to spreading-activation theory (e.g., Dell et al., 2008), this effect occurs because it is easier for words than for non-words to become activated because they have representations in the lexicon. Errors should be anticipation errors because all the words in the sentence are activated in speech planning (Nooteboom & Quené, 2013a). Anticipation errors should turn into exchange errors. Anticipation and exchange errors generally involve words moving only a short distance within the sentence.

While this model explains much of the data, it de-emphasises the processes involved in constructing meaning. It does not predict the time taken to produce words. The interactive processes suggested by this model do not appear to occur in errorless speech. There is insufficient detail regarding the level of interactions that should occur.

Dell et al. (1997) developed an extended spreading-activation theory, arguing that most speech errors belong to the following two categories:

- Anticipatory – spoken ahead of their time and mainly reflecting inexpert planning.
- Perseverated – spoken later and reflecting a failure in monitoring or planning.

The key assumption was that expert speakers plan ahead more than do non-expert speakers, and so a higher proportion of their speech errors will be anticipatory. Dell et al. (1997) gave participants extensive practice on a tongue-twister and, although the total numbers of errors decreased, the proportion that was anticipatory increased. Anticipatory errors also increase with age (Vousden & Maylor, 2006) and speed of speech.
**WEAVER++**

The computational model WEAVER++ (Word-form Encoding by Activation and VERification) was proposed by Levelt et al. (1999). The model focuses on processes involved in producing individual spoken words and is based on the following assumptions:

- There is a feed-forward activation-spreading network.
- The three main levels are:
  - lexical concepts;
  - *lemmas* (abstract words);
  - *morphemes* (basic units of meaning) with their phonemic segments.
- Lexical (word) selection depends on a competitive process based on the number of lexical units activated.
- Processing stages follow each other in serial fashion.
- Speech errors are avoided by means of a checking mechanism.

In the process of *lexicalisation*, a semantic representation is translated into its phonological representation in stages. A lemma is selected at the lexical selection stage. The basic word form of the lemma is selected during morphological encoding. Syllables of the word are computed during phonological encoding.

**WEBLINK:** [WEAVER++ on the web](#)

Van Turenout et al. (1998) found, using ERPs with Dutch participants, that syntactic information about a noun’s gender was available 40 ms before its initial phoneme. Indeed, Indefrey (2011) suggests the time course for speech production:

- Conceptual preparation takes about 200 ms.
- After that, lemma retrieval takes 75 ms.
- Phonological code retrieval takes 20 ms per phoneme and 50–55 ms per syllable.
- Finally, there is phonetic encoding with articulation typically starting about 600 ms after the initiation of processing.

The “tip-of-the-tongue” state probably occurs when the lemma (abstract word) has been activated but phonological processing is unsuccessful. It occurs when links between semantic and phonological systems are weak. Harley and Bown (1998) found that phonologically unusual words were much more susceptible to the “tip-of-the-tongue” effect. This occurs because phonologically unusual words are hard to retrieve. Vigliocco et al. (1997) found evidence for this in Italian participants who could guess the grammatical gender of words they could not produce. However, Biedermann et al. (2008) found German participants were not more successful at guessing the first phoneme of words when they had access to gender information, casting doubt on the notion that syntactic information is available before phonological information.

Piai et al. (2014) considered activation in the left superior frontal gyrus, reflecting the processing effort involved in resolving the competition among competing words. There was greatest activation on trials with related distractors and least on trials with identical distractors. According to the model, lemma selection is completed *before* phonological information is accessed. Most evidence is inconsistent with this. Meyer and Damian (2007) found naming of target pictures was faster with phonologically related distractors.

Mädebach et al. (2011) found picture naming was slowed in the presence of a phonologically similar distractor word when the demands on processing resources were relatively low. However, there was no effect of phonological similarity when processing demands were high. Serial processing (as predicted by Levelt) is found when processing demands are high. In contrast, processing is more interactive (as predicted by Dell) when processing demands are low.
The WEAVER++ model has some successes. The notion that word production involves a series of stages is reasonable. This theoretical approach has shifted the emphasis away from speech errors towards precise timings of word production. It is a simple model with testable predictions.

However, the model has some limitations. It has a narrow emphasis on the production of single words. There is more interaction between the different levels of processing than assumed. There is evidence that parallel processing occurs during speech production. The need for lemmas is not clear. Some findings with anomia are inconsistent with the data.

**INTERACTIVE EXERCISE: WEAVER++**

According to Dell’s spreading-activation theory, speech production involves semantic, syntactic, morphological and phonological levels, with processing being parallel and interactive. The theory accounts for most speech errors, but predicts more errors than are actually found. According to the WEAVER++ model, the production of individual words is serial and proceeds from lexical selection to morphological encoding to phonological encoding. Experimental evidence supports the processing sequence assumed within the model. However, the assumption that lemma selection is completed before activation of phonological information is incorrect and parallel processing probably does occur during speech production.

- **Cognitive neuropsychology: speech production**

  There is an important distinction between Broca’s and Wernicke’s aphasia:

  - *Broca’s aphasia* is described as slow, non-fluent speech with poor syntactic ability but largely intact comprehension. The lesion is in the frontal lobe.

    WEBLINK: [Broca’s aphasia video](#)

  - *Wernicke’s aphasia* is described as fluent, grammatical speech, which often lacks meaning, associated with severe comprehension problems. This lesion is in the posterior temporal lobe.

    WEBLINK: [Wernicke’s aphasia video](#)

Yang et al. (2008) found in stroke patients that most of those with damage to Broca’s area had language deficits associated with Broca’s aphasia. In similar fashion, those with damage to Wernicke’s area mostly had language problems associated with Wernicke’s aphasia. This distinction, however, is oversimplified. Patients typically display a variety of symptoms (Harley, 2013) and the brain regions involved in speech production involve both regions (Berwick et al., 2013). De Bleser (1988) studied patients with Wernicke’s and Broca’s aphasia. Some patients had damage to both language areas. Dick et al. (2001) noted that patients with Wernicke’s aphasia who speak richly inflected languages (e.g., Italian, German) make a comparable number of grammatical errors to patients with Broca’s aphasia.

WEBLINK: [Aphasia characteristics](#)

Nearly all aphasics (regardless of the type of aphasia) suffer from *anomia*, which is an impaired ability to name objects. The speech of these patients is normally low in content and lacking fluency. Levelt et al.’s WEAVER++ model (1999) describes two main reasons for anomia:

- There may be a problem in lemma or abstract word selection, in which case errors in naming would be similar in meaning to the correct word.

- There could be a problem in word-form selection, in which case patients would be unable to find the appropriate phonological form of the word.
Howard and Orchard-Lisle (1984; DOI: 10.1080/02643298408252021; see Eysenck & Keane, 2010, p. 437) described a case of anomia (patient JCU) involving semantic impairment (deficient lemma selection). Kay and Ellis (1987) studied patient EST, who could select the right lemma but not the phonological form of the word. His condition resembles the “tip-of-the-tongue” state. Anomia can result from an early semantic stage (finding the correct word) or a later phonological stage (generating the word’s phonological form) (Laganaro et al., 2008). Word selection can be influenced by phonological activation and this can enhance or impair performance depending on whether the cue is correct or incorrect, suggesting an interaction between semantic and phonological processing. The findings supported interactive models over serial ones (Soni et al., 2009).

Patients who can apparently find the appropriate words but not order them grammatically suffer from agrammatism. Patients with agrammatism typically produce short sentences containing content words (e.g., nouns, verbs) but lacking function words (e.g., the, in, and) and word endings. This is also known as non-fluent aphasia. Grodzinsky and Friederici (2006) identified three phases of syntactic processing occurring in different brain areas:

- Local phrase structures are formed after word category information (e.g., noun, verb) has been obtained. This phase involves the frontal operculum and anterior superior temporal gyrus.
- Dependency relationships among the various sentence elements are calculated (i.e., who is doing what to whom?). This phase occurs in Broca’s area (BA44/45).
- Syntactic and lexical information is integrated in the posterior superior temporal gyrus and sulcus.

Beeke et al. (2007) argued that the artificial tasks used may lead researchers to underestimate the abilities of agrammatic patients. Burkhardt et al. (2008) suggested patients with agrammatism have a processing limitation rather than loss of the necessary syntactic knowledge. Christianson et al. (2010) found agrammatic patients showed impaired sequence learning as well as grammaticality. The research of Griffiths et al. (2013) indicates two brain pathways are necessary for effective syntactic processing.

Patients suffering from jargon aphasia apparently show the opposite pattern to agrammatic aphasics. These patients appear to speak fairly grammatically, but have difficulty finding the right words. They frequently substitute one word for another and often produce neologisms (made-up words). Most jargon aphasics are typically not aware of errors in their speech (poor self-monitoring). Neologisms tend to include phonemes that:

- resemble the target word;
- are common consonants;
- were recently used.

Butterworth (1985) reported evidence that jargon aphasics do modify their neologisms to make them fit syntactically. Olson et al. (2007; DOI: 10.1080/02643290601137017; see Eysenck & Keane, 2010, p. 441) studied patient VS. Her neologisms were affected in similar ways by word frequency, imageability and length, suggesting a single underlying deficit. Sampson and Faroqi-Shah (2011) obtained two relevant findings with five jargon aphasics. First, there was a strong negative correlation between self-monitoring and their production of jargon (neologisms + real words unrelated phonologically to the target word). Second, masking noise that prevented the patients from hearing the sound of their own voices led to reduced self-monitoring and increased use of jargon.

A distinction used to be drawn between Broca’s aphasia and Wernicke’s aphasia, based in part on the brain regions involved. No rigid distinction is possible, and there are doubts about the precise brain areas involved. Patients with anomia have an impaired ability to name objects. Some anomic patients have problems with lemma selection, whereas others have problems with word-form selection. Patients with agrammatism generally produce the appropriate words when speaking, but cannot order them grammatically. The syntactic deficiencies of agrammatic aphasics sometimes extend to language comprehension. Patients with jargon aphasia sometimes speak fairly grammatically (with numerous exceptions). They have severe problems with word finding, and produce made-up words that often resemble the correct word phonemically. Jargon aphasics are generally unaware they are producing made-up words. Agrammatic aphasics and jargon aphasics show some evidence for
a double dissociation between syntactic planning and content word retrieval, but the evidence is less strong than used to be believed.

- **Speech as communication**

Overt speech nearly always occurs within a social context where the primary goal is to communicate with other people. “Traditional mechanistic accounts of language processing derive almost entirely from the study of monologue. Yet, the most natural and basic form of language use is dialogue.” In other words, speech production and speech comprehension are interwoven (Pickering & Garrod, 2013, p. 169).

Grice (1967) argued that the key to successful communication was cooperation between speaker and listener. He proposed the Cooperative Principle, and four maxims the speaker should heed:

- **Maxim of quantity** – the speaker should be as informative as necessary.
- **Maxim of quality** – the speaker should be truthful.
- **Maxim of relation** – the speaker should say things that are relevant.
- **Maxim of manner** – the speaker should make his/her contribution easy to understand.

Many speakers do not follow these maxims due to self-interest (Faulkner, 2008).

Speakers and listeners work together to maximise common ground – mutual beliefs, expectations and knowledge. In a conversation, cooperation is exhibited in terms of smooth switches between speakers. Conversation moves from one speaker to another via an adjacency pair. Speakers typically make various assumptions about the listener when establishing common ground:

- **Global assumptions** (e.g., the listener’s preferred language, the listener’s general knowledge, shared personal experiences).
- **Local assumptions** concerning what the listener knows.

Horton and Keysar (1996) distinguished two theoretical positions:

- **Initial design model**. Based on the principle of optimal design, the speaker’s plan for an utterance takes full account of common ground.
- **Monitoring and adjustment model**. Speakers plan their utterances initially on the basis of information available to them without considering the listener’s perspective. These plans are then monitored and corrected to take into account common ground.

Horton and Keysar (1996) tested these models, and their findings fit the predictions of the monitoring and adjustment model better. Shintel and Keysar (2009) suggest speakers rely on powerful, simple and cheap cues to communicate effectively. Ferreira (2008) argued that speakers choose easy utterances by producing accessible material sooner and less accessible material later. Fukumura and van Gompel (2012) reported evidence that speakers do not always take account of listeners’ knowledge. Perspective taking is resource demanding. Wardlow (2013) obtained a correlation of +0.42 between perspective-taking ability and inhibitory control. One technique to make better use of the resources is through syntactic priming. Syntactic priming occurs when a previously experienced syntactic structure influences the speaker’s current processing. Galati and Brennan (2010) argued that the probability of speakers focusing on audience design is highest when listeners’ needs are clear and simple. Speakers can modify their language based on whether listeners have heard what they’ve said before (Galati & Brennan, 2010).

Many speakers also make use of gestures to aid communication. Holler and Wilkin (2011) compared speakers’ gestures before and after listener feedback. There were two main findings:

- The number of gestures reduced when the listener indicated understanding of what had been said.
- Feedback encouraging clarification, elaboration or correction was followed by more precise, larger or more visually prominent gestures.

Speakers blind since birth use gestures even when speaking to blind listeners (Iverson & Goldin-Meadow, 1998).
Prosodic cues include rhythm, stress and intonation. Snedeker and Trueswell (2003) argued that prosodic cues are much more likely to be provided when the meaning of an ambiguous sentence is not clarified by the context. Speakers consistently produced prosodic cues regardless of whether the listener needed them and whether they realised the listener needed disambiguating cues (Kraljic & Brennan, 2005).

A final way speakers enhance listener comprehension is with discourse markers. Discourse markers are words or phrases that assist communication even though they are only indirectly relevant to the speaker’s message. Speakers use the discourse markers oh and um to indicate problems in deciding what to say next. Listeners realise that is what speakers mean (Tree, 2007).

RESEARCH ACTIVITY: Discourse markers

A key to successful communication is the Cooperative Principle, according to which speakers and listeners must try to be cooperative. Speakers generally take account of the common ground they share with their listener(s), and are responsive to the verbal and non-verbal reactions of any listeners. However, speakers and listeners may lack the processing resources necessary to maximise common ground. According to the interactive alignment model, automatic processes such as syntactic priming may be used to help speakers and listeners achieve common ground.

- Writing: the main processes

Writing extended texts involves several processes. Writing is basically a form of thinking. However, it is not separate from other cognitive activities. Hayes and Flower (1986) identified key processes in writing:
- planning
- sentence generation
- revision.

Chenoweth and Hayes (2003) developed Hayes and Flower’s (1986) theoretical approach. Their model identifies four processes:
- Proposer: proposes ideas for expression and is engaged in higher-level processes of planning.
- Translator: converts the message formed by the proposer into word strings (e.g., sentences).
- Transcriber: converts the word strings into written or word-processed text.
- Evaluator/reviser: monitors and evaluates what has been produced and engages in revision of deficiencies.

We can identify the processes involved in writing by using directed retrospection. Kellogg (1994) found writers devoted about 30% of their time to planning, 50% to sentence generation and 20% to revision. Kellogg (1988) found writers who produced outlines spent more time in sentence generation, but less time in planning and reviewing. Producing an outline also increased the quality of the letter. Levy and Ransdell (1995) found consistent individual differences in writing style were revealed by looking at the typical sequence in which the various processes were used. Beauvais et al. (2011) also found writers switch rapidly between different processes. According to Hayes and Flower (1980), writers have a monitor controlling their processing activities. Quinlan et al. (2012) argued that the monitor requires working-memory resources.

CASE STUDY: Sentence generation

Writing expertise

Unsurprisingly, individuals with high levels of writing expertise generally have more reading experience (Daane, 1991). Bereiter and Scardamalia (1987) identified two major strategies used in the planning stage:
- a knowledge-telling strategy;
- a knowledge-transforming strategy.
With increasing expertise, there is a shift to the knowledge-transforming strategy (Kellogg & Whiteford, 2012). Hayes and Bajzek (2008) found individuals familiar with technical terms greatly overestimated other people’s knowledge of these terms – this is the knowledge effect.

Expert writers are more likely than non-expert ones to use the knowledge-transforming strategy (Kellogg & Whiteford, 2012). Chuy et al. (2012) pointed out that the knowledge-transforming strategy involves a content problem space. Successful use of the planning process depends on the writer’s knowledge. Expert writers also use revision more effectively. Hayes et al. (1985) found expert writers detected 60% more problems in a text than did non-experts. Levy and Ransdell (1995) found that those writers who produced the essays of highest quality spent 40% more time revising and reviewing.

**RESEARCH ACTIVITY:** Knowledge-telling and knowledge-transforming strategies

**Working memory**
Most people find writing difficult and effortful. Kellogg and Whiteford (2012) argued that this is because writing makes much use of working memory, which has limited capacity. Vanderberg and Swanson (2007) found individuals with the most effective central executive functioning had the best writing performance at the general and specific levels. Essay quality in children was predicted by working memory capacity (Connelly et al., 2012). Ardila and Surloff (2006) argued with supporting evidence that many patients with dysexecutive syndrome have difficulties planning and organising their ideas on writing tasks and in maintaining attention. They proposed the term dysexecutive agraphia to refer to such patients. Chenoweth and Hayes (2003) found writers were slower and made more errors on a transcription task when accompanied by articulatory suppression. Kellogg et al. (2007) found that the visuo-spatial sketchpad was more involved when writers were thinking about concrete objects than abstract ones.

The main limitation of Kellogg’s theoretical approach is that it does not indicate clearly why processes such as planning or sentence generation are so demanding. It would be useful to go beyond demonstrations that the central executive, phonological loop and visuo-spatial sketchpad are involved in writing to reveal the ways in which these components of the working memory system combine and interact in the writing process.

**WEBLINK:** Olive (2003)

Most evidence suggests the increase in the use of word processors in recent years has been a good thing. Goldberg et al. (2003) found students who use computers when learning to write are more engaged in writing and produce longer and higher quality work. Kellogg and Mueller (1993) compared text produced by word processor and by writing in longhand.

**WEBLINK:** Improve your essay writing skills!

Writing involves planning, sentence generation and revision, but these processes cannot be separated neatly. On average, writers devote about 30% of their time to planning, 50% to sentence generation and 20% (or less) to revision. Planning makes use of conceptual, sociocultural and strategic knowledge. Good writers use a knowledge-transforming rather than knowledge-telling strategy, and this helps them to produce high-level main points. Good writers also spend more time revising than do other writers, and are better at detecting problems in a text. The processes involved in writing typically make large demands on working memory, especially its central executive component. Composition places more demands on working memory than does transcription, and the demands are even greater when writers engage in composition and transcription at the same time. It is not entirely clear why composition is so demanding. The use of word processors in writing has generally had a positive impact on writing performance, although word processing probably does not have a dramatic impact on writing quality.

- Spelling
Spelling has been the subject of considerable research. Planton et al. (2013) identified three brain areas involved in writing:

- intraparietal sulcus and superior parietal lobule in the left hemisphere: this area is involved in the selection and/or representation of letter shapes;
- superior frontal sulcus in the left hemisphere: this area seems to be the interface between abstract letter combinations and the generation of motor commands;
- posterior cerebellum in the right hemisphere: this area is probably most involved in motor activity.

Rapp and Dufour (2011) suggest there are two main routes between hearing a word and spelling it:

- the lexical route;
- the non-lexical route.

Both routes use a graphemic buffer.

WEBLINK: www.funbrain.com/spell/

If a brain-damaged patient could make little or no use of the non-lexical route, then they would spell known words accurately but have problems with unfamiliar or non-words. This is phonological dysgraphia. Evidence that accurate spelling can occur with no use of the non-lexical route was reported by Shelton and Weinrich (1997), who studied EA. EA could not write non-words but wrote 45% of irregular words correctly. Children with phonological dysgraphia performed considerably worse than healthy controls on all these tests of phonological processing (Cholewa et al., 2010).

A patient with damage to the lexical route would have some success in giving appropriate spellings of non-words. The patient would be more accurate with regular than irregular words and would produce misspellings sounding like the word. This is a patient with surface dysgraphia. Evidence of the involvement of the semantic system in surface dysgraphia was reported by Macoir and Bernier (2002). Their patient, MK, had spelling that was much better for words about which she could access semantic information. Cholewa et al. (2010) found children with surface dysgraphia spelled 56% of irregular or inconsistent words wrongly but only 19% of non-words.

INTERACTIVE EXERCISE: Rapp and Dufour (2011)

There is increasing evidence that the lexical and non-lexical routes to spelling often interact. Rapp et al. (2002) studied LAT, a patient with Alzheimer’s disease who spelled using the non-lexical route. LAT sometimes integrated information from lexical and non-lexical processes when spelling familiar words. Martin and Barry (2012) found evidence for lexical influences on non-word spelling, where non-words were spelled by analogy to real words heard immediately beforehand. Delattre et al. (2006) found it takes longer to write irregular words than regular words, suggesting irregular words produce conflict between the outputs of lexical and non-lexical routes.

Tainturier et al. (2006) reported the case of CWS, a 58-year-old man who had had a stroke. His ability to spell words was severely impaired, whereas his ability to read words was almost intact. This may indicate that there are two lexicons. However, much evidence suggests participants’ reading and writing abilities will correlate (Holmes & Carruthers, 1998).

CASE STUDY: Differences in spelling ability between deaf and hearing students

It is generally assumed there are separate lexical and non-lexical routes in spelling, with the former being used to spell familiar words and the latter being used to spell unfamiliar words and non-words. Both routes make use of a graphemic buffer that briefly holds graphemic representations. Patients with phonological dysgraphia have damage to the lexical route, whereas those with surface dysgraphia have damage to the non-lexical route. There
is evidence from unimpaired individuals and from brain-damaged patients that information from the two routes is sometimes integrated. There has been controversy as to whether the same orthographic lexicon is used in reading and spelling. Most of the evidence is consistent with the single-lexicon position. Some patients with damage to the graphemic buffer find it hard to spell long words.