18 Word and multiword processing: Cognitive approaches

1. Introduction

As language speakers, we have a 'store' of words and multiword sequences that we produce and recognize (see Textbox 18.1). This store can be thought of as our mental dictionary, which we refer to as the lexicon and the items within it as lexical entries (for a discussion of approaches to word recognition and encoding in bilinguals see Gor, 2021 in this volume). Researchers who study the lexicon are interested in what information lexical entries contain, how the entries are organized, and how comprehenders access entries in their lexicon. It is the last question that is the focus of the current chapter, where we will look at arguably the most significant determinant of word and multiword recognition and processing in a first language (L1) and a second language (L2): word frequency.

Recognizing single words and multiword sequences involves a complex set of processes that are influenced by a wide range of variables. Frequency, or how often comprehenders encounter a word or sequence, plays a central role in the entrenchment and processing of lexical entries. Words and sequences that are encountered frequently are recognized and responded to more quickly than those that are encountered less often, while those that are rarely encountered are responded to more slowly yet (e.g., 'cat' vs. 'rat' vs. 'gnat'). Frequency effects have been found in tasks that present words on a computer screen and measure decision/response times (RTs). For example, in a word naming task, participants say frequent words aloud more quickly than infrequent ones, and in a lexical decision task (deciding whether a string of letters is a word or not), frequent words elicit faster 'yes' responses than less frequent ones (e.g., Forster & Chambers, 1973; Hudson & Bergman, 1985). In eye-tracking, there are fewer and shorter eye fixations on high-frequency words (e.g., Rayner & Raney, 1996). Word frequency generally explains 30% to 40% of the variance in L1 word recognition tasks (Brysbaert, Stevens, Mandera, & Keuleers, 2016) and more than any other variable (e.g., Balota et al., 2004; Whaley, 1978). Word frequency effects have also been demonstrated in the L2 (e.g., Diependaele, Lemhöfer, & Brysbaert, 2013; Whitford, Pivneva, & Titone, 2016). Similar to single words, there is faster recognition and processing for more frequent multiword sequences in the L1 (e.g., Siyanova-Chanturia, Conklin & van Heuven, 2011). Evidence of a frequency advantage for multiword sequences in the L2 is somewhat mixed (for discussion see Conklin, 2019).

A range of other factors are known to influence single-word processing, albeit to a lesser extent than frequency: word length; age of acquisition (AoA); and neighborhood size (both number and frequency), as well as the regularity of neighbors' grapheme-to-phoneme correspondence (for an overview see Harley, Chapter 6, 2014). The impact of such factors has been well documented in the L1, and some work has been done exploring these factors the L2 (for a discussion see Dijkstra & van Heuven, 2018). Another important factor in word processing is a word's predictability (McDonald & Shillcock, 2003): more predictable words have decreased processing times, and in reading tasks, highly predictable words are often skipped altogether (Ehrlich & Rayner, 1981; McDonald & Shillcock, 2003). Predictability has important implications for the processing of multiword items. For example, the word *abject* predicts a very limited set of upcoming words (e.g., *poverty, failure, misery, horror, terror, apology*), with some of the combinations being multiword items (e.g., the collocation *abject poverty*). Crucially, the predictability of these upcoming words will (largely) be predicated on language exposure—in other words the frequency of their co-occurrence. For a word to become predictable, it will need to have occurred in the same and/or a very similar context a sufficient number of times.

In addition, a considerable amount of research has looked at how cross-language overlap influences single- and multi-word recognition and processing in bilinguals, even when the social and linguistic context calls for the use of only one language (for reviews see Conklin & Carrol, 2018; Dijkstra & van Heuven, 2018). This has primarily been investigated using words that share lexical properties across languages: cognates overlapping in semantics and phonology, as well as orthography for languages that share a script, as in *table*$_{\text{English}}$, *table*$_{\text{French}}$ and テーブル $_{\text{Japanese}}$ ('teburu')[1]; interlingual homographs overlapping in orthography and somewhat in phonology, but not semantics, as in *pain*$_{\text{English}}$-'hurt', *pain*$_{\text{French}}$-'bread'; and interlingual homophones overlapping in phonology but not orthography or semantics, as in /kle/ for *clay*$_{\text{English}}$-'stiff, sticky fine-grained earth that can be molded', *clef*$_{\text{French}}$-'key'. Multiword items can also overlap across languages in various ways, as demonstrated by the following English and French examples: meaning and form (e.g., *throw money out the window/jeter l'argent par les fenêtres*, literally in both languages 'to throw money out of the windows' and figuratively 'to waste money'); and meaning but not form (e.g., *feel blue/avoir le cafard*, literally in French 'to have the cockroach' and figuratively in both languages 'to feel sad').

As a whole, research on cognates and interlingual homographs and homophones demonstrates that word recognition is language independent, meaning that all lexical representations that are similar to (i.e., have form overlap with) the input are activated (for review, see Conklin & Carrol, 2018; Dijkstra & van Heuven, 2018; van Hell & Tanner, 2012; and for a meta-analytic review of cognates Lauro & Schwartz, 2017). Activation is mediated by the amount of phonological, orthographic and semantic overlap between the words in the two languages (e.g., for discussion see Dijkstra & van Heuven, 2018; and for examples in different script languages, see Allen & Conklin, 2013; 2017). It can further be influenced by the biasing strength of the sentence context (Whitford et al., 2016). Investigations of cross-language overlap in multiword items have primarily focused on idioms and collocations. Overall, research points to a cross-language effect, such that L1-L2 overlap benefits multiword processing (Conklin & Carrol, 2018; yet see Beck & Webber, 2016).

18.1 Key Terms and Concepts

Lexicon – the mental 'store' of words and other linguistic expressions (e.g., idioms) that is thought to have information about their form (phonological and orthographic), meaning, and morphological and syntactic properties.

Lexical entries – the items that are stored in long-term memory with information about the sound and meaning of words and frequent multiword strings (e.g., idioms 'kick the bucket', phrasal verbs 'put off', etc.). Entries also include information about the morphological and syntactic properties of the items.

Multiword sequences – sequences of words that are: 1) recurrent in language, occurring more frequently than comparable novel phrases; and 2) (generally) processed more quickly than matched novel phrases. Multiword sequences encompass a broad range of phenomena that fulfil a number of communicative functions, such as: binomials *bride and groom*; collocations *abject poverty*; idioms *kick the bucket*; lexical bundles *you know what*, and phrasal verbs *pick up*. The terms multiword units/sequences, formulaic language, formulaic units/sequences are often used interchangeably.

Interactive Activation (IA) model – a computational model for word recognition. Each word has an activation level and is recognized when its activation level passes the activation threshold. A word's activation level is influenced by the activation levels of other words including neighbors.

Neighbors - orthographic and phonological neighbors are words that differ from one another by only one letter or sound respectively. For example, the word 'hint' has the neighbors 'hilt, 'hind', 'hunt', 'mint', 'tint', 'flint', 'lint', 'pint', etc.

Resting Level Activation (RLA) – activation level of a word in the absence of any input and interaction.

Activation threshold – critical value that the activation level of a word has to exceed for it to be recognized.

2. Critical issues and Topics

2.1 Frequency and single-word recognition

Of all of the variables that influence word recognition, word frequency is by far the most powerful predictor of RTs (Whaley, 1978). Indeed, it has been said that frequency of occurrence should be given 'its rightful place as a fundamental shaper of a lexical system always dynamically responsive to experience' (Monsell, 1991: 150). The impact of word frequency on RTs is generally called a 'frequency effect'. However, it is important to note that what word frequency refers to varies. In some studies, word frequencies are those extracted from a corpus (with a possible distinction between word form and lemma, see Deshors & Gries, 2021, in this volume), while in other investigations, word frequency refers to the number of occurrences of that particular word in an experiment. Despite these differences, frequency effects likely arise because each encounter with an item strengthens the memory traces that make up its lexical representation (Murray & Forster, 2004), which raises its Resting Level Activation (RLA).

It is important to note that there is a limit to how fast the processing system can get; it reaches what we call an asymptote. This means that once a word has received a certain amount of exposure, recognition cannot get any faster even with additional exposure to that item. Consequently, additional exposure effects high- and low-frequency words differently. We can understand this better in terms of the words in Figure 18.1A: 'gnat' that is low frequency, 'rat' that is higher frequency, and 'cat' that is even higher frequency. We can see that at occurrence *x*, 'gnat' has a lower RLA than 'rat' and 'cat', and in turn 'rat' has a lower RLA than 'cat'. As is illustrated in the figure, words with lower RLA are farther away from the activation threshold. Note that an additional occurrence (*x*+1) raises the RLA of 'gnat' much more than that of 'rat' or 'cat', and that of 'rat' more than that of 'cat'. Further, we see that eight exposures yield much less change for the RLA of 'cat' than they do for 'gnat'. Thus, at each occurrence 'gnat' has a much bigger shift toward the activation threshold/asymptote, although the shift is less with each additional occurrence. In contrast, 'cat' moves less with each additional occurrence, as it already starts near the threshold/asymptote.

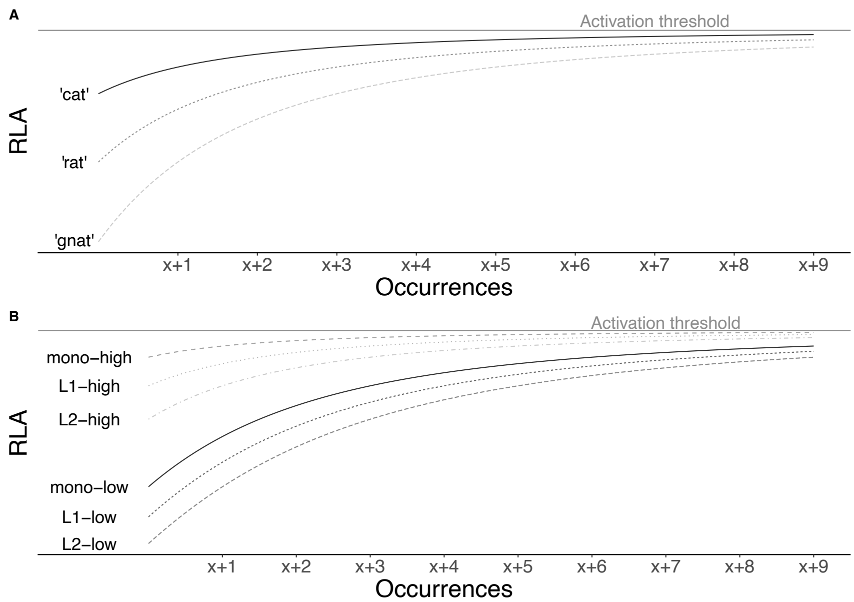

Figure 18.1 Panel A. Effect of additional occurrences on low frequency 'gnat', higher frequency 'rat' and even higher frequency 'cat', demonstrating that exposure to a lexical item raises its RLA in proportion to its distance from the activation threshold/asymptote. Panel B. Effect of additional occurrences on monolingual high- and low-frequency words and bilingual L1 and L2, high- and low-frequency words, demonstrating that increased exposure in bilinguals has a greater effect on RLA. Curves labelled mono-high and mono-low refer to high- and low-frequency words for monolinguals respectively, while L1-high and L2-high denote high-frequency words in a bilingual's L1 and L2 respectively and L1-low and L2-low denote low-frequency words the L1 and L2.

It is important to consider how frequency effects are impacted by speaking more than one language. Learning, knowing and using more than one language means that language use is by necessity divided. In other words, second language speakers generally use both of their languages (L2 and L1) less frequently than monolinguals use their one language. This gives rise to reduced lexical entrenchment, which has been accounted for in different ways. One view holds that the connections between an item's orthographic form, phonological form and its meaning are strengthened as a function of exposure. When there is less use, this results in weaker ties between an item's form (phonology, orthography) and concepts (e.g., Weaker Links Hypothesis: Gollan, Montoya, Cera, & Sandoval, 2008). An alternative view is that using more than one language leads to reduced RLA of L2 words and potentially L1 words as well (e.g., Bilingual Interactive Activation Plus Model, BIA+: Dijkstra & van Heuven, 2002).

Thus, knowing an L2 reduces lexical entrenchment (i.e., the strength of word and multiword representations in memory)—possibly even in the L1—which in turn leads to more of an effect of frequency (i.e., a greater increase in RLA with additional exposures). This can be understood in terms of Figure 18.1B. We see that, in monolinguals, high-frequency words start very close to the asymptote. In unbalanced bilinguals, while L1 high-frequency words also start close to the asymptote they are not as close as the high-frequency monolingual ones. Therefore, more exposure should have more of an impact on their RLA. L2 high-frequency words are further still from the asymptote, as are L1 and L2 low-frequency words in turn. In unbalanced bilinguals, this means that increased exposures should have a greater impact on particular words: L2 low-frequency words > L1 low-frequency words > L2 high-frequency words > L1 high-frequency words. Further, more exposures should raise RLA more in bilinguals than monolinguals and, thus, we would expect more of an effect of increased frequency in bilinguals.

Indeed, research has demonstrated that there is a greater effect of frequency for bilinguals in their L2 than L1. In a lexical decision task with unbalanced Dutch-English bilinguals, Duyck, Vanderelst, Desmet and Hartsuiker (2008) found a frequency effect that was almost twice as large in the L2 than L1. Using eye-tracking during paragraph reading with unbalanced English-French and French-English bilinguals, Whitford and Titone (2012) found larger frequency effects in gaze duration and total reading time in the L2 than L1. Further, the effect was modulated by the current level of exposure, such that the greater the L2 exposure prior to the study, the smaller the frequency effects. It is important to note that Figure 18.1B predicts smaller frequency effects in monolinguals than for bilinguals in their L1 (i.e., less change in RLA with increased exposures for monolinguals). However, this has not always been found to be the case. An investigation by Cop, Keuleers, Drieghe and Duyck (2015) demonstrated that frequency effects are similar for monolinguals and unbalanced bilinguals in their L1 and that larger frequency effects in bilinguals are driven by a disproportionate lowering of the RLA of low-frequency words.

A consequence of higher RLA is faster processing. More precisely, single- and multi-word items that are more frequent are processed more quickly because they are closer to the activation threshold. This has been found for single words in the L1 and L2 across a range of tasks (for a discussion see Brysbaert, Mandera, & Keuleers, 2018; Cop et al., 2015; Diependaele et. al, 2013; Monaghan, Chang, Welbourne, & Brysbaert, 2017).

2.2. Frequency and multiword units

At the outset of this chapter, it was suggested that multiword sequences demonstrate frequency effects akin to those of single-word items. This means each and every occurrence of a multiword item in the L1 and L2 contributes to its entrenchment in memory, with more encounters leading to faster processing. Research has demonstrated that, in the L1, children and adults are sensitive to the frequency of multiword sequences, with more frequent multiword items being processed more quickly than less frequent ones (for discussion, see Conklin 2019; Siyanova-Chanturia & Sidtis, 2018).

When studying the processing of multiword sequences, the frequency of the sequences themselves is generally not what is under investigation. Instead, the processing of multiword sequences is compared to that of matched ‘novel’ language. In other words, frequently co-occurring word sequences are compared to word sequences that rarely or never co-occur (e.g., idiom *spill the beans* vs. matched *spill the chips*). In the L1, a processing advantage is generally observed for multiword sequences relative to matched controls, but this advantage is not always found in the L2, in particular for idioms (e.g., Conklin & Schmitt 2008; Siyanova-Chanturia, Conklin, & Schmitt 2011). Idioms may be problematic for learners (both L1 children and L2 children and adults) because computing the meaning of the individual words does not generally yield the figurative meaning (e.g., *spill* + *the* + *beans* ≠ ‘reveal a secret’). If exposure strengthens the links between an item’s form and meaning, it may simply be that learners have not encountered idioms a sufficient number of times for a strong connection to develop between the form (*spill the beans*) and meaning (‘reveal a secret’). In fact, amongst the various types of multiword items, idioms tend to be fairly low frequency.

Since the processing advantage for multiword sequences is not always observed in the L2, it has been hypothesized that processing is more compositional (i.e., word-by-word) in the L2, which makes the properties of the individual words and their meanings more salient than phrase-level features like frequency and meaning (Ciéslicka, Heredia, & Olivares 2014). Thus, L2 speakers encountering *kick the bucket* would be more likely to arrive at the meaning ‘strike a pail with the foot’ than ‘die’. In contrast, a usage-based approach, in which the linguistic system is shaped by experience with language (e.g., Bybee, 2013; Tomasello, 2003), would say that, if a processing advantage is not evident for multiword sequences, it is simply that learners have not encountered the sequences a sufficient number of times for them to become entrenched in memory and for a processing advantage to emerge. A set of studies by Carrol and Conklin (2014, 2017) explored this question using lexical decision and eye-tracking. English monolinguals and Chinese/L1-English/L2 speakers read English idioms and controls (*spill the beans/chips*) and translated Chinese idioms and controls (*draw a snake and add feet/hair*). The latter did not exist in English and were translated into sequences that had a frequency of zero in English, but which were well known in Chinese. In line with previous research, Carrol and Conklin found a processing advantage for English idioms for monolinguals but not for L2 speakers. Crucially, the Chinese speakers had a processing advantage for Chinese idioms translated into English compared to their controls, demonstrating that frequent multiword sequences that are entrenched in memory do show the typical processing advantage in the L2.

Research on more compositional multiword sequences (i.e., sequences where the meaning is the sum of its parts such as *salt* + *and* + *pepper* = 'salt and pepper') generally demonstrates a processing advantage relative to matched controls (e.g. 'pepper and salt') as well as a sensitivity to frequency in the L2, such that more frequent sequences are processed more quickly than less frequent ones (for an overview see Conklin 2019; Siyanova-Chanturia & Sidtis, 2018). Thus, much like with single word items, every occurrence of a multiword item in both the L1 and L2 contributes to its entrenchment memory, with more encounters leading to faster processing.

3. Theoretical perspectives and approaches

In order to better understand and explain word recognition, as well as the role of frequency in it, computational models have been developed. Such models contain variables that are thought to characterize the word recognition system as well as rules that describe how these variables interact and evolve over time. These rules reflect our beliefs about the dynamic processes that unfold during word recognition. Simulations typically explore how model variables change over time as model parameters are adjusted. Through the interplay of model parameters, variables and proposed rules, computational simulations can provide us with insight into the cognitive processes that underlie word recognition in the L1 and L2 (Norris, 2013).

A main goal of these models is to quantitatively explain and/or predict measured RTs (i.e., the time needed to make a response in a task and/or read a word in eye-tracking) and their distributions. It is important to note that we expect a distribution of RTs because of frequency. For example, given a specific word such as 'cat', we can measure RTs of that word across numerous participants. Due to individual differences – including different degrees of exposure to the word (i.e., the word frequency) – RTs will differ among participants and hence have a particular distribution. Alternatively, we could measure RTs for several words, such as 'cat' vs. 'rat' vs. 'gnat', from single participants. We would expect a distribution of RTs due to their different frequencies.

While computational models differ in their mathematical complexity and conceptual foundations, they all share a common key principle: RTs are determined by the time that it takes a word (or multiword sequence) to reach a predefined activation threshold. In one of the main classes of models, each word has an activation level, and at heart, these models describe how a word's activation level changes over time. The details of the mechanisms that are responsible for changing activation levels vary greatly between different models. Nevertheless, all models require a link between word frequency and a component of the model, such as its RLA. We will illustrate this by focusing on interactive activation (IA) models pioneered by McClelland and Rumelhart (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). In particular, we will discuss the representation of word frequency in Multilink, a bilingual IA model (Dijkstra et al., 2018).

In an interactive activation model (McClelland & Rumelhart, 1981), the RLA of a word is thought to be determined by its frequency, while in distributed connectionist approaches (e.g., Plaut, 1997; Seidenberg & McClelland, 1989), the strength of the connections between processing units (which are linked to e.g. orthography or phonology) is a function of word frequency. Multilink (Dijkstra, et al., 2018) is a recently developed IA model that accounts for bilingual word recognition, production and translation. It is based on the Bilingual IA (BIA) model and its successor, the BIA+ model (Dijkstra & van Heuven, 1998, Dijkstra & van Heuven, 2002). In IA models, each word has its own activation level and a specific word is recognized if its activation level crosses a pre-defined threshold faster than any other word (or letter string in lexical decision tasks). The time that it takes to reach the threshold is the RT. Crucially, interactions between words can substantially impact RTs. These interactions, which can be either excitatory or inhibitory, occur at various levels including phonology, orthography and semantics. In the absence of any input or interaction, activation levels are assumed to decay to a baseline value, which corresponds to the RLA. Importantly, each word has its own RLA, and words typically differ in their RLAs. In Multilink, the BIA+ and the BIA models, word frequency is linked to the RLA. This notion was already put forward by McClelland and Rumelhart (1981) who remarked that high-frequency words should have higher RLAs than low-frequency words. Thus, words with higher RLAs (i.e., high-frequency words) have shorter RTs compared to those with lower RLAs (i.e., low-frequency words). While the relationship between RT and RLA appears intuitive, a hallmark of computational models is their ability to make quantitative predictions and explain observed data. As a consequence, we need to translate the verbal relationships between RT, RLA and word frequency into formal links.

When thinking about how to relate RLA to RT, we should start by keeping in mind that IA models track the temporal evolution of activation levels, which means that they require an initial value for a word's activation level. At the beginning of an experimental trial, each word is at rest (it has not received any input yet), meaning that a word's activity level equals its RLA. If we assume that the activation level for each word grows at a constant rate and is independent of the activation level of any other word (i.e., neglecting the aforementioned interactions from phonology, orthography and semantics), RTs are proportional to the distance between the RLA and the activation threshold. This is equivalent to saying that RTs and RLA are linearly related and establishes a formal relationship between RLA and RT. Moreover, the finding that high-frequency words are recognized more quickly than low-frequency words entails that, for a fixed activation threshold, the RLA for high-frequency words is higher than that for low-frequency words. It is important to note that this relationship between word frequency and RLA is a prediction of the model, which is consistent with the intuition put forward by McClelland and Rumelhart (1981). Figure 18.2 illustrates the connection between RLA and RT. Each solid straight line represents the time evolution of the activation level of a word starting from its RLA (open upright triangle) until it reaches the activation threshold (open upside-down triangle). In addition, we see the distributions for RT and RLA, respectively, and how a certain RLA is mapped onto an RT value (solid dots and dashed lines). Because the relationship between RLA and RT is linear, it entails that the RLA distribution has the same shape as the RT distribution, only stretched, reversed and moved along the y-axis.

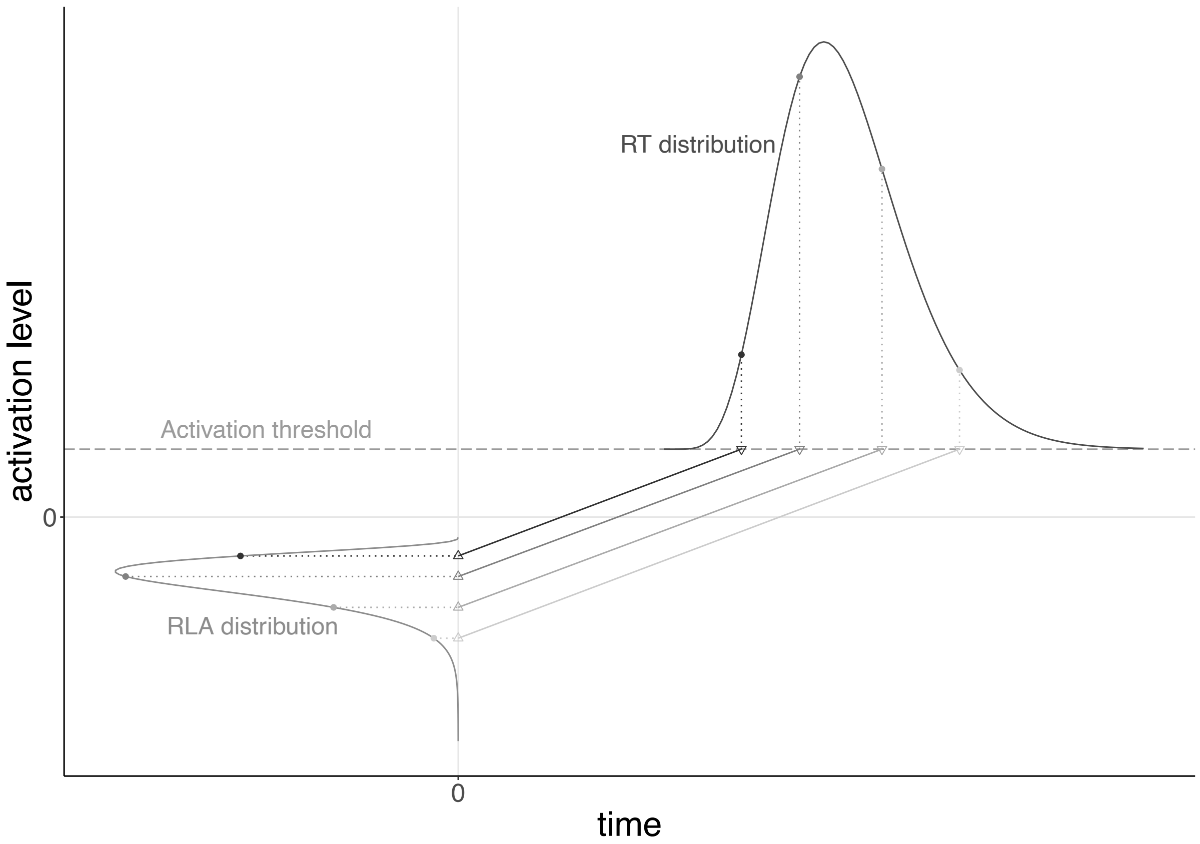

Figure 18.2 Relationship between RLA and RT distribution. Each solid straight line represents the time evolution of the activation level for a word starting from a specific RLA (open upright triangle) until the activation threshold is reached (open upside-down triangle).

Figure 18.2 illustrates how a given RLA yields a corresponding RT. To explain frequency effects in RTs, we also need to relate word frequency to RLA. So how would we do this? Consider the solid black line in Figure 18.2. It maps a high RLA to a short RT. Since high-frequency words have short RTs, we can also interpret the black line as relating a high RLA to a high-frequency word. Analogously, the light grey line relates a low RLA to a long RT. Given that long RTs are associated with low frequency words, this connection can be understood as linking a low frequency word with a low RLA. The important point here is that because we know the quantitative relation between RLA and RT, we can use it to establish a quantitative relationship between word frequency and RLA.

In Figure 18.2, we assume that the relationship between RLA and RT is linear. Crucially, it can be shown on conceptual grounds that RLA and RTs should be linearly related in Multilink. Hence, we can use the argument presented above to quantitatively link word frequency and RLA in Multilink. It is important to emphasize that not only do Multilink simulations result in a linear relationship between RLA and RT, but that this should be true *a priori*.

3. Current trends and future directions

As we have seen, frequency plays a prominent role in single word and multiword sequence processing. This is in line with usage-based approaches to language acquisition and processing, in which exposure (i.e., frequency) leads to entrenchment in memory, with increased exposure yielding stronger entrenchment (e.g. Bybee, 2013; Tomasello, 2003). It is important to point out that frequency measures from corpora are often viewed as an index of linguistic experience (i.e., exposure). Thus, if word *y* (or multiword sequence *y*) is frequent in a large, representative corpus, it is assumed that speakers have encountered it more than word *z* (or sequence *z*) that is less frequent in the corpus. Intuitively we know that corpora do not provide a metric of all of a speaker's wide and varied experience with language. As Gernsbacher (1984) notes, corpora only provide an approximation of actual exposure, which may be particularly problematic for low-frequency words. A study by Gardner, Rothkopf, Lapan and Lafferty (1987) demonstrated that engineering students were faster at making a lexical decision to low-frequency engineering words while nurses were faster for low-frequency medical words. Thus, corpus frequency does not necessarily align with actual experience with a language, even in the L1. Crucially, to draw convincing conclusions about the relationship between input and processing, we need to have a more accurate picture of the input, in particular in the L2. As we will see, recent work has been attempting to do this, and future work should build on these initial findings.

One way to relate input to processing is to establish what input learners actually receive. While this is extremely challenging, in some contexts it may be possible—for example when learners get very little L2 exposure outside of the classroom and textbooks. Across several studies, Northbrook and Conklin (2018; 2019; submitted) looked at just such a situation. First, Northbrook and Conklin (2018) created a corpus of Japanese Ministry of Education mandated junior high school English textbooks. They compared the most frequent textbook lexical bundles (a type of multiword sequence) to those in a native speaker reference corpus. They found that, although lexical bundles were very frequent in the textbooks and were similar to those in a native-speaker corpus at shorter lengths (3-word lexical bundles), they deviated considerably at longer ones (4-, 5- and 6-words). Northbrook and Conklin (2019) found that junior high school students had a processing advantage for frequent 3-word lexical bundles from their textbooks (*do you play*) but not matched ones that were frequent in a native speaker corpus (*do you hear*) that did not occur in their textbooks. Notably, the processing advantage showed a frequency effect, such that more frequent multiword sequences in the textbook were processed more quickly than less frequent ones. Thus, young EFL learners were not only sensitive to whether or not items occurred in their texts, but also to the frequency of occurrence of a given item in them. Northbrook and Conklin (submitted) demonstrate that Japanese learners of English found the textbook multiword sequences more natural than matched native-English sequences many years after junior high school and their perception of naturalness varied with the frequency of the items in the texts. Thus, initial input and its frequency appears to have long-lasting effects, which is a finding that needs further exploration.

Another way to explore the relationship between input and processing is to provide the input in an experimental context (for some examples see, Godfroid et al. 2018; Pellicer-Sánchez, 2017). Such studies have presented L2 speakers with existing multiword items; however, even with pre-tests to assess knowledge, we cannot be certain that the items had never been encountered before. Alternatively, researchers have used nonwords; however, attention may unduly be drawn to these items, as they are unknown 'words'. A recent study by Conklin and Carrol (2020) addressed these concerns by monitoring monolingual English readers' eye movements while reading short stories containing existing binomials (a type of multiword sequence, like *time and money*) and novel ones (*wires and pipes*). In line with the wider literature, they found a processing advantage for existing multiword sequences. At the beginning of the story there was no processing advantage for the novel multiword sequences. However, after encountering them four or five times, an advantage emerged. This happened during the course of reading a story, demonstrating that the frequency of occurrence of multiword items allows them to become entrenched in memory and to elicit a processing advantage. However, there are many open questions that remain to be explored (see Textbox 18.2), such as, how long-lasting/durable the processing advantage is; if exposure is spread across multiple texts and/or days, how many occurrences are needed for a processing advantage to emerge; and how the difficulty of the text impacts the emergence of a processing advantage.

18.2 Open questions and future directions

i. *Beyond frequency for single words in the L2*. A wide range of factors are known to influence L1 word processing. Do we see effects in the L2 akin to those in the L1 for length, predictability, taboo and emotion-laden words, etc.?

ii. *Frequency in multiword sequences*. Are frequency effects for multiword items in the L2 similar to those for single-word items in the L1 and is this the same across multiword sequence types (e.g., idioms, collocations, binomials, lexical bundles, etc.)?

iii. *RLA beyond word frequency.* Currently, RLA is most commonly computed from word frequencies alone. How does the value of RLA change if other factors are taken into account such as neighbors, AoA, etc.?

iv. *Interaction strength.* In IA models, nodes representing orthographic, phonological, and semantic features interact with each other. How do we determine the strengths of these connections in a principled manner?

v. *Varied populations, languages and contexts*.[2] Research on word and multiword processing has primarily focused on adult L2 learners in university contexts. We need far more research on a greater range of populations like young learners, and learners in classroom vs. immersion contexts. We need to investigate a wider range of languages expanding the focus beyond English and other European languages. We need to understand processing in more natural contexts and in production instead of simply in comprehension.

4. Further reading

Dijkstra, T., & van Heuven, W. J. B. (2018). Visual word recognition in multilinguals. In S.-A. Rueschemeyer & M. G. Gaskell (Eds). *The Oxford Handbook of Psycholinguistics, 2nd Edition*. Oxford University Press.

This chapter discusses single-word visual processing in multilinguals. It has a strong focus on cognate and interlingual homograph representation and processing.

Conklin, K. (2020). Processing single- and multi-word items. In S. Webb (Ed). *Routledge Handbook of Vocabulary Studies*. Routledge.

This chapter discusses single- and multi-word processing, with a focus on the influence of word frequency and linguistic overlap.

Conklin, K., & Carrol, G. (2018). First language influence on the processing of formulaic language in a second language. In A. Siyanova-Chanturia & A. Pellicer-Sánchez (Eds.), *Understanding Formulaic Language: A Second Language Acquisition Perspective.* Routledge.

This chapter provides a detailed overview of the influence of cross-language overlap (congruency) on the processing of multiword items, in particular on idioms, collocations, and translated formulaic language.

5. References

Allen, D., & Conklin, K. (2013). Cross-linguistic similarity and task demands in Japanese-English bilingual processing. *PLoS ONE*, *8*(8), 1-14.

Allen, D., & Conklin, K. (2017). Naturalistic reading in the L2 and the impact of word frequency and cross-linguistic similarity. *Journal of the Ochanomizu University English Society*, *7*, 41-57.

Balota, D. A., Cortese, M. J., Sergent-Marshall, S. D., Spieler, D. H., & Yap, M. J. (2004). Visual word recognition of single-syllable words. *Journal of Experimental Psychology: General*, *133*(2), 283-316.

Beck, S. D., & Weber, A. (2016). Bilingual and monolingual idiom processing is cut from the same cloth: The role of the L1 in literal and figurative meaning activation. *Frontiers in Psychology*, *7*, 1350.

Brysbaert, M., Mandera, P., & Keuleers, E. (2018). The word frequency effect in word processing: An updated review. *Current Directions in Psychological Science*, *27*(1), 45-50.

Brysbaert, M., Stevens, M., Mandera, P., & Keuleers, E. (2016). The impact of word prevalence on lexical decision times: Evidence from the Dutch Lexicon Project 2. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(3), 441-458.

Bybee, J. (2013). Usage-based theory and exemplar representation' In T. Hoffman & G. Trousdale (Eds.), *The Oxford Handbook of Construction Grammar* (pp. 49-69). Oxford University Press.

Carrol, G., & Conklin, K. (2014). Getting your wires crossed: Evidence for fast processing of L1 idioms in an L2. *Bilingualism: Language and Cognition*, *17*(4), 784-797.

Carrol, G., & Conklin, K. (2017). Cross language priming extends to formulaic units: Evidence from eye-tracking suggests that this idea “has legs”. *Bilingualism: Language and Cognition*, *20*(2), 299-317.

Cieślicka, A. B., Heredia, R. R., & Olivares, M. (2014). It’s all in the eyes: How language dominance, salience, and context affect eye movements during idiomatic language processing. In M. Pawlak & L. Aronin (Eds.), *Essential Topics in Applied Linguistics and Multilingualism* (pp. 21-41). New York: Springer International Publishing.

Conklin, K. (2019). Processing single- and multi-word items. In S. Webb (Ed.), *Routledge Handbook of Vocabulary Studies* (pp. 174-188). London: Routledge.

Conklin, K., & Carrol, G. (2020). Words go together like “bread and butter”: The rapid, automatic acquisition of lexical patterns. *Applied Linguistics*. Online First.

Conklin, K., & Carrol, G. (2018). First language influence on the processing of formulaic language in a second language. In A. Siyanova-Chanturia and A. Pellicer-Sánchez (Eds.), *Understanding Formulaic Language: A Second Language Acquisition Perspective* (pp. 62-67). London: Routledge.

Conklin, K., & Schmitt, N. (2008). Formulaic sequences: Are they processed more quickly than nonformulaic language by native and nonnative speakers? *Applied Linguistics*, *29*(1), 72-89.

Cop, U., Keuleers, E., Drieghe, D., & Duyck, W. (2015). Frequency effects in monolingual and bilingual natural reading. *Psychonomic Bulletin & Review*, *22*(5), 1216-1234.

Deshors, S., & Gries, S. (2021). Using corpora in research on L2 psycholinguistics. In A. Godfroid and H. Hopp (Eds). *Routledge Handbook of Second Language Acquisition and Psycholinguistics*. Routledge.

Diependaele, K., Lemhöfer, K., & Brysbaert, M. (2013). The word frequency effect in first and second language word recognition: A lexical entrenchment account. *Quarterly Journal of Experimental Psychology, 66*(5)*,* 843-863.

Dijkstra, T., & van Heuven, W. J. B. (1998). The BIA Model and Bilingual Word Recognition. In J. Grainger, & A. Jacobs (Ed.), *Localist connectionist approaches to human cognition* (pp. 189-225). Lawrence Erlbaum Associates Publishers.

Dijkstra, T., & van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(3), 175-197.

Dijkstra, T., & van Heuven, W. J. B. (2018). Visual word recognition in multilinguals. In S.-A. Rueschemeyer & M. G. Gaskell (Eds.), *The Oxford Handbook of Psycholinguistics, 2nd Edition* (pp. 118-143). Oxford, UK: Oxford University Press.

Dijkstra, T., Wahl, A., Buytenhuijs, F., Van Halem, N., Al-Jibouri, Z., De Korte, M., & Rekké, S. (2018). Multilink: a computational model for bilingual word recognition and word translation. *Bilingualism: Language and Cognition, 22*(4), 657-679.

Duyck, W., Vanderelst, D., Desmet, T., & Hartsuiker, R. J. (2008). The frequency effect in second-language visual word recognition. *Psychonomic Bulletin & Review*, *15*(4), 850-855.

Ehrlich, S. F., & Rayner, K. (1981). Contextual effects on word perception and eye movements during reading. *Journal of Verbal Learning and Verbal Behavior*, *20*(6), 641-655.

Forster, K. I., & Chambers, S. M. (1973). Lexical access and naming time. *Journal of Verbal Learning and Verbal Behavior*, *12*(6), 627-635.

Gardner, M. K., Rothkopf, E. Z., Lapan, R., & Lafferty, T. (1987). The word frequency effect in lexical decision: Finding a frequency-based component. *Memory & Cognition*, *15*(1), 24-28.

Gernsbacher, M. A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology: General*, *113*(2), 256-281.

Godfroid, A., Ahn, J., Choi, I., Ballard, L., Cui, Y., Johnston, S., ... & Yoon, H. J. (2018). Incidental vocabulary learning in a natural reading context: An eye-tracking study. *Bilingualism: Language and Cognition*, *21*(3), 563-584.

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language, 58*(3), 787-814.

Gor, K. (2021). Word and multi-word processing: Linguistic approaches. In A. Godfroid and H. Hopp (Eds). *Routledge Handbook of Second Language Acquisition and Psycholinguistics*. Routledge.

Harley, T. A. (2014). *The psychology of language: From data to theory* (4th ed.). London, UK: Psychology Press.

Hudson, P. T., & Bergman, M. W. (1985). Lexical knowledge in word recognition: Word length and word frequency in naming and lexical decision tasks. *Journal of Memory and Language*, *24*(1), 46-58.

Lauro, J., & Schwartz, A. I. (2017). Bilingual non-selective lexical access in sentence contexts: A meta-analytic review. *Journal of Memory and Language*, *92*, 217-233.

López, B., & Vaid, J. (2018). Fácil or A piece of cake: Does variability in bilingual language brokering experience affect idiom comprehension? *Bilingualism: Language and Cognition*, *21*(2), 340-354.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review*, *88*(5), 375-407.

McDonald, S. A., & Shillcock, R. C. (2003). Eye movements reveal the on-line computation of lexical probabilities during reading. *Psychological Science*, *14*(6), 648-652.

Monaghan, P., Chang, Y. N., Welbourne, S., & Brysbaert, M. (2017). Exploring the relations between word frequency, language exposure, and bilingualism in a computational model of reading. *Journal of Memory and Language*, *93*, 1-21.

Monsell, S. (1991). The nature and locus of word frequency effects in reading. In D. Besner and G.W. Humphreys, eds., *Basic Processes in Reading: Visual Word Recognition* (pp. 148-197). Hillsdale, NJ: Erlbaum.

Murray, W. S., & Forster, K. I. (2004). Serial mechanisms in lexical access: the rank hypothesis. *Psychological Review*, *111*(3), 721-756.

Norris, D. (2013). Models of visual word recognition. *Trends in cognitive sciences, 17*(10), 517-524.

Northbrook, J., & Conklin, K. (2019). Is what you put in what you get out? —Textbook-derived lexical bundle processing in beginner English learners. *Applied Linguistics, 40*(5), 816-833.

Northbrook, J., & Conklin, K. (2018). "What are you talking about?" – An analysis of lexical bundles in Japanese junior high school textbooks. *International Journal of Corpus Linguistics, 23*(3), 311-334.

Northbrook, J., & Conklin, K. (submitted). "That sounds about right" – An examination of lexical bundle naturalness intuitions in native and non-native English speakers.

Pellicer-Sánchez, A. (2017). Learning L2 collocations incidentally from reading. *Language Teaching Research*, *21*(3), 381-402.

Plaut, D. C. (1997). Structure and function in the lexical system: Insights from distributed models of word reading and lexical decision. *Language and Cognitive Processes*, *12*(5-6), 765-806.

Rayner, K., & Raney, G. E. (1996). Eye movement control in reading and visual search: Effects of word frequency. *Psychonomic Bulletin & Review*, *3*(2), 245-248.

Rumelhart, D. E., & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: Part 2. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review, 89*(1), 60-94.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*(4), 523-568.

Siyanova-Chanturia, A., Conklin, K., & Schmitt, N. (2011). Adding more fuel to the fire: An eye-tracking study of idiom processing by native and non-native speakers. *Second Language Research*, *27*(2), 251-272.

Siyanova-Chanturia, A., Conklin, K., & van Heuven, W. J. (2011). Seeing a phrase "time and again" matters: The role of phrasal frequency in the processing of multiword sequences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *37*(3), 776-784.

Siyanova-Chanturia, A., & Janssen, N. (2018). Production of familiar phrases: Frequency effects in native speakers and second language learners. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44*(12), 2009–2018.

Siyanova-Chanturia, A., & Sidtis, D. V. L. (2018). What online processing tells us about formulaic language. *Understanding Formulaic Language: A Second Language Acquisition Perspective* (pp. 38-61). London: Routledge.

Tomasello, M. (2003). *Constructing a Language: A Usage-Based Theory of Language Acquisition*. Cambridge, MA: Harvard.

van Hell, J. G., & Tanner, D. (2012). Second language proficiency and cross-language lexical activation. *Language Learning*, *62*(s2), 148-171.

Whaley, C. P. (1978). Word-nonword classification time. *Journal of Verbal Learning and Verbal Behavior, 17*(2), 143-154.

Whitford, V., Pivneva, I., & Titone, D. (2016). Eye Movement Methods to Investigate Bilingual Reading. In: R.R. Heredia, J. Altarriba and A.B. Cieślicka (Eds.), *Methods in Bilingual Reading Comprehension Research* (pp. 183-211). New York: Springer Science+ Business Media LLC.

Whitford, V., & Titone, D. (2012). Second-language experience modulates first- and second-language word frequency effects: Evidence from eye movement measures of natural paragraph reading. *Psychonomic Bulletin and Review*, *19*(1), 73-80.

NOTES

[1] In linguistic terms, Japanese words like *table/テーブル*' ('teburu') are in fact 'loanwords' because they have been borrowed into the language. However, it is the overlap in form and meaning that underpins the processing advantage for cognates and not their linguistic origins. Because loanwords share form and meaning, they are treated as cognates in the processing literature.

[2] There have been some recent studies on more varied populations, for example López and Vaid (2018) investigated informal translators or 'language brokers'. There has also been some recent work on multiword sequence production (Siyanova-Chanturia & Janssen, 2018). However, far more of this type of work is needed.