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The eyes have it

An eye-movement study into the processing of formulaic sequences

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Introduction

There is a consensus among applied linguistic scholars that the use of formulaic sequences contributes to fluent, well-formed, and appropriate language (e.g. Pawley and Syder, 1983; Nattinger and DeCarrico, 1992; Wray, 2002; Schmitt and Carter, this volume). The underlying belief is that preformulated sequences of language, which are stored in the mind as wholes, can be recognized and retrieved with a minimum amount of processing effort, which facilitates quick and accurate language use. However, the actual mechanics of the processing of formulaic sequences have been inadequately researched. Much of the research into formulaic sequences has either been corpus-based and descriptive, or acquisition-based, which focuses on sequences which have been produced by language novices, either L1 or L2. There has been relatively little use of the rigorous experimental paradigms from the field of psychology which could shed light on the underlying processing mechanisms. This study will take advantage of one such methodology, the study of eye-movement during the reading of texts, to explore how formulaic sequences are processed, by investigating how they are read in context.

The eye-movement paradigm

When reading a page of text our eyes do not move in a continuous sweep across the page but rather the movement tends to be noticeably jerky, stopping several times a second to inspect a word. Occasionally the reader may choose to move back to a part of the text that they have previously fixated upon or they may jump over several words to land in a previously uninspected part of the page.

After the jerky movement or *saccade* has been completed, the eyes come to rest, and this resting time is known as a *fixation*. Typically, readers fixate for 200–250 msec between saccadic movements that last 20–30 msec, and information is extracted from the page only while their eyes are stationary. Although readers of alphabetic scripts such as English move their eyes in a regular left-to-right fashion, they occasionally do go back to a point in the text that may have been previously fixated, or to text that may have been passed over during a saccade. These return fixations are known as *regressions* and they occur on average 10–15% of the time for a normal adult reader. Regressive fixations are usually launched to areas of the text that have caused linguistic confusion, or contain particularly difficult words. More detailed descriptions of the characteristics of readers' eye movements can be found in Rayner (1998), Underwood and Batt (1996) and Underwood (1998).

The appeal of measuring eye movements is that they give an indication of what processes are occurring in the reader's mind. This assumption is based on the reports that the number of regressions and forward fixations increase with text difficulty, and that they tend to be of a longer duration than those associated with less complex text. Furthermore, poor readers tend to make more regressive fixations on a piece of text than good readers (Tinker, 1958).

There is a considerable body of evidence which supports Just and Carpenter's (1980) theory that fixations provide an "on-line" indication of reading difficulty that also involves moment-to-moment control of the dynamics of reading. When fixating a relatively important part of the field, our eyes will remain stationary for a duration that is indicative of the increased amount of processing that is being performed. The extreme version of this theory proposes that words that are not fixated are not processed. Just and Carpenter's theory is in fact based on two assumptions, the immediacy assumption which states that "the reader tries to interpret each content word of a text as it is encountered", and the eye-mind assumption that "the eye remains fixated on a word as long as the word is being processed. So the time it takes to process a newly fixated word is directly indicated by the gaze duration" (Just and Carpenter, 1980: 330). Support for this model comes from a variety of sources in which high and low frequency words are embedded in sentences that are to be read for comprehension. Word frequency is a potent determiner of fixation duration. For example, Inhoff and Rayner (1986) and Rayner and Duffy (1986) compared the fixations on sentences such as *The heavy rain damaged the crops* with those on *The heavy* *hail damaged the crops*. The word *hail* has a lower frequency of occurrence than the word *rain,* and the fixation durations on these two target words were 262 msec and 225 msec respectively. As frequency decreases, so the amount of time required to extract the necessary information from the word increases. This effect is not a product of the relationship between frequency and length. Low frequency words do tend to contain more letters than high frequency words, but when words of similar length are compared, high frequency words gain shorter fixations, and this holds for short words as well as for longer words (e.g., Underwood, Binns & Walker, 2000). Words that need more visual processing receive longer fixations, and explaining the frequency effect is a primary goal of theoretical models of eye movement control in reading (Reichle, Pollatsek, Fisher & Rayner, 1998).

Just and Carpenter (1980) have provided data which showed that during the reading of paragraphs taken from scientific text, the length of the inspection was directly related to the difficulty of processing. For example, one participant looked at the word *question* for 300 msec, whilst they looked at the equally long but less frequent word *transfer* for 633 msec. Additional support for the on-line approach comes again from Carpenter and Just (1983) who showed that gaze duration on a target was not influenced by the length or frequency of the preceding word. They concluded that cognition is locked on to fixation and that there is no influence of material prior to or ahead of fixation; thus fixation durations are indicative of the processing of the word that is being fixated.

A major source of evidence that suggests that our eyes are under the control of the cognitive processes involved in sentence comprehension comes from studies of the sensitivity to sentence contexts. Ehrlich and Rayner (1981) showed that during the reading of passages participants fixated words that were predicted by the preceding context less often (51% of the time) than words appearing in neutral contexts (fixated 62% of the time). If the target was predictable and it was fixated, the fixation duration was shorter than if the same target had been fixated but appeared in neutral context (221 vs 254 msec). Words that are to some extent predictable by their preceding contexts can be thought of as being easier to recognize, and this ease of processing is again indicated by shorter fixation durations. In the present study we asked whether the short contexts available in familiar idioms and other formulaic sequences such as *on the other hand* and *as a matter of fact* can also provide sufficient context to facilitate the processing of their terminating word, and also whether this facilitation effect would be seen in a group of readers less familiar with these English expressions.

Methodology

Selection of the target formulaic sequences

This study is focused on the processing, rather than identification, of formulaic sequences, and so we wished to use unambiguous cases as our targets. We also wished to include a range of formulaic sequence types, including lexical phrases (Nattinger and DeCarrico, 1992), transparent metaphors, sayings/proverbs, and idioms. To compile a list of potential formulaic sequences for this study, the lists used in the Schmitt, Dörnyei, Adolphs, and Durow (this volume) acquisition study were first consulted and 45 potential candidates were identified for the lexical phrases category. In order to obtain clear cases of the other categories, the *Oxford Learner's Dictionary of English Idioms* (1994) was consulted and an additional 40 candidates were extracted.

The 85 candidate phrases were then subjected to a frequency analysis in two corpora: the British National Corpus and the CANCODE. Candidates with relatively low frequencies were deleted from the list. In addition to being frequent, the technicalities of the eye-movement methodology (see procedure below) meant that certain additional criteria were necessary to remain as a candidate sequence:

- the sequence had a relatively obvious beginning, i.e. it did not begin with several function words
- the sequence did not finish with a function word
- the sequences were 4–8 words long
- the sequences were relatively predictable from their initial components.

The assumption was that the more frequent sequences were also more likely to be well-known. To confirm this assumption, the remaining 21 formulaic sequences were embedded in a modified cloze test with short contexts, such as the following example:

> Steve thinks Sue is quite pretty, but I don't think so at all. But as they say, "Beauty is in the e___ o___ t___ b___."

This instrument was given to 30 native first-year undergraduates. One sequence was produced by only four participants and was eliminated. The remaining twenty sequences were all well-known, being produced by 28–30 participants. The two exceptions were *the straw that broke the camel's back* (19) and *keep your nose to the grindstone* (17), which were still known by the majority of participants.

The twenty sequences were then embedded in twenty extended contexts, with each context story containing one target formulaic sequence. In addition each context contained the terminal word from a formulaic sequence from another passage. By comparing terminal words when they appear in a formulaic sequence and when they appear in non-formulaic text, we are able to control for any individual characteristics of the words that may prompt variability in fixation behaviour, such as word length, word frequency or part of speech. In the example below, the target sequence is *beat around the bush* and the non-formulaic terminal word is *basket*, from the idiom *put all your eggs in one basket* in another context story.

> You've been talking in circles for 30 minutes trying to tell me something. Please don't beat around the bush for another half an hour, but just get to the point and tell me! If it was you who dropped my flower basket, don't worry because I won't be angry with you.

The contexts were subjected to frequency analysis through the *The Compleat Lexical Tutor (v.2)* (Cobb, 2003) to ensure that low frequency vocabulary was kept to a minimum, so that non-native speakers would have no problems reading the context stories. Finally, a simple comprehension question for each context was devised to ensure participants read the contexts conscientiously. The question for the passage above is:

> Did someone drop the flower basket?
> (Answer Yes)

The vocabulary-controlled contexts were then formatted in Word using black Helvetica font, size 8, spacing = 0.5, with line spacing set to double. Care was taken to ensure that each target sequence appeared near the middle of its line in the passage, and was not split between lines. Finally, this text was pasted and centred onto plain white bitmaps of dimension 1024 × 768 pixels for display on the apparatus computer monitor. (See appendix for the complete passages.)

Apparatus

An SMI Eyelink system was used to take eye-movement measures. In the Eyelink system, a head-mounted high-speed camera takes an image of the right pupil every 4ms, and an on-line parser uses a velocity threshold of 30°/second to allocate samples into saccades with the resting point between them defined as fixations or blinks. A chin rest was used to minimise head movements. Passages were displayed on a 36 × 27 cm monitor with a resolution of 1024 × 768 pixels.

Procedure

Participants were seated at a fixed viewing distance of 70cm from the computer monitor with their head mounted on a chin rest. The SMI eye-tracking device was then placed on the participant's head, and the camera positioned at an optimal viewing point to record the activity of the right pupil. A 9-point calibration procedure was then applied, and when successful, the experiment began.

Each trial of the experiment began with a drift-correct display consisting of a centrally presented circle on which the participant needed to maintain a stable fixation. This procedure helps re-align the system with eye position in the event of small head-movements. The experimenter terminated the drift-correct procedure when a satisfactory fixation was achieved. A fixation cross followed in the top left of the screen for 1 second, to allow the participant to position their eyes at the beginning of the text. The fixation cross was then replaced by a passage of text. The participant was able to read each passage freely with no time constraints until they felt able to answer the simple comprehension question, upon which they pressed either the left or right arrow key and the passage was replaced by the question. Each question required either a yes response (right arrow key) or a no response (left arrow key). Participants were told to guess if uncertain. Once a response had been made, the drift correct screen appeared marking the onset of the following trial. Each participant read each passage (20 in total) before being debriefed as to the nature of the experiment and paid for participation.

Participants

Two groups of participants were tested: native and non-native speakers. Each group consisted of 20 mainly postgraduate students studying at the University of Nottingham. Thirteen of the nonnatives had Chinese as their mother tongue, and the rest spoke a variety of L1s. Their degree of L2 competence was not controlled for, but it can be assumed to be relatively high, because they were all studying at an English-medium university, with a minimum undergraduate entrance requirement of CBT TOEFL 213 (Paper TOEFL 550) or IELTS 6.0. All participants had normal or corrected-to-normal vision.

Results

Analysis was conducted on the fixations only. All fixations less than 100ms were removed from analysis, as it is assumed that on-line cognitive processes do not influence short fixations. The measures that were collected included the mean number of fixations made on all words in the passages, the durations of those fixations, the number of fixations on the terminal words (when in a formulaic sequence and when in a non-formulaic context), and the durations of the fixations on those terminal words. These measures are shown in Table 1.

The total number of fixations made on all passages and the durations of these fixations provide an overall indication of differences in the reading dynamics of the two groups of readers. These differences are indicated when informally comparing Figures 1 and 2. Figure 1 shows the pattern of fixations, and their durations, made by one of the native English speakers while reading one of the passages. This contrasts with the pattern in Figure 2 (a non-native speaker reading the same passage), where there are more fixations and the durations are more variable. There is also more variability among participants in the non-native speaker group, relative to the native speakers, and this is indicated in the larger standard deviations shown in Table 1. Comparisons between readers were made for the two measures using unrelated t-tests. Native speakers made fewer fixations overall than non-native speakers ($t_{38} = 4.76, p < 0.001$), averaging less than one fixation per word in contrast with the non-native speakers' average of almost one and a half fixations per word. The duration of those fixations also varied, with native speakers dwelling upon each word for reliably less time ($t_{38} = 3.11, p < 0.01$).

The number of fixations on each terminal word (in sequence and out of sequence) were compared for the two groups of readers using a mixed-design

Table 1. Eye movement measures recorded during the reading of the passages (Standard deviations are shown in parentheses.)

	Native speakers	Non-native speakers
Mean number of fixations on all words in all passages	0.92 (1.94)	1.40 (3.14)
Mean fixation duration on all words in all passages (msec)	201 (25.6)	228 (29.2)
Mean number of fixations on terminal words in formulaic sequences	0.71 (0.24)	1.37 (0.56)
Mean number of fixations on terminal words in non-formulaic contexts	0.86 (0.30)	1.46 (0.43)
Mean fixation duration on terminal words in formulaic sequences (msec)	179 (31.5)	247 (62.2)
Mean fixation duration on terminal words in non-formulaic contexts (msec)	210 (54.3)	249 (41.3)

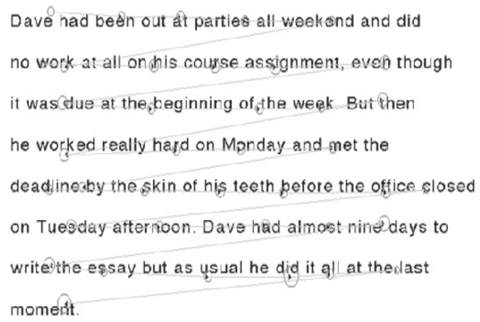

Figure 1. Fixations on a passage read by a native English speaker. Each fixation is indicated by a circle here, and with larger circles indicating longer fixations. The lines joining the fixation-circles are representative of the reader's saccadic eye movements. In this particular passage, the formulaic sequence is *by the skin of his teeth* (line 5), and the terminal word from a formulaic sequence that formed part of another passage is the word *nine* (line 6). Note the regular left-to-right sequence of fixations along each line of text, the high proportion of words that are not fixated at all, and the consistency of fixation durations indicated by the sizes of the circles superimposed on the text

analysis of variance. Native speakers fixated the terminal words less often than the non-native speakers ($F_{1,38} = 27.7, p < 0.001$), and terminal words in the final position in formulaic sequences gained fewer fixations than the same words in non-formulaic contexts ($F_{1,38} = 7.24$, $p < 0.05$). The interaction between these factors was not reliable. The fixation durations on the terminal words were also inspected with a mixed-design analysis of variance. Native speakers had shorter fixations on target words than did non-native speakers ($F_{1,38} = 14.55, p < 0.001$), and words in formulaic sequences gained shorter fixations ($F_{1,38} = 6.37, p < 0.05$).

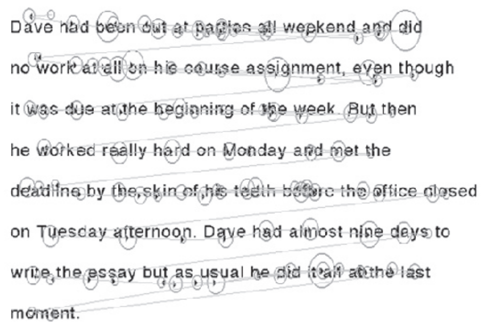

Figure 2. Fixations on a passage read by a non-native English speaker. Note the greater number of fixations (following forward and regressive movements) and the greater variability of their durations

These differences were qualified by an interaction ($F_{1,38} = 5.50, p < 0.05$), that was further inspected with an analysis of simple main effects. For the native speakers, there was a reliable difference between terminal words in and out of formulaic sequences ($F_{1,38} = 11.86, p < 0.01$), but for non-native speakers the difference between words was not reliable ($F < 1$). Table 1 indicates a 31 msec difference between formulaic and non-formulaic terminal words for the native speakers, but a difference of only 2 msec for the non-native speakers.

Discussion

The results show that the native speakers were more fluent readers than the non-native participants. The advantage for the natives was consistent across the various measures, including fewer and shorter fixations on all words in the twenty contexts, and fewer and shorter fixations on the terminal words. Although it is unsurprising that that the natives would be more proficient readers, the non-natives were relatively advanced in their English, studying at the same university as the natives and having passed the university's language entrance requirements. Thus, the short context stories, in which low frequency vocabulary had been controlled, should not have proved overly challenging, but it still seems that even relatively proficient nonnatives process written text less efficiently than educated natives. This is indicated by the fact that nonnatives fixated on each word 1.4 times on average, and is particularly obvious when we observe the actual tracking during reading, as illustrated in Figure 2. The nonnatives tended to have many regressions, and most of the words were fixated, often more than once. Conversely, the natives had relatively uniform fixations, evenly spaced through the text (Figure 1). Natives apparently need to sample less of the text than nonnatives, mainly the content words, with many function words remaining unsampled.

This efficiency of sampling also held true for the terminal words where natives fixated less than the nonnatives in both formulaic/nonformulaic conditions. This result reflects the general reading advantage of the natives. But the key comparison is between terminal words within and outside of formulaic sequences. Both participant groups fixated words less often when those words were part of a formulaic sequence than when those words were embedded in non-formulaic text. This means that the participants had less need to sample those words when they were in formulaic sequences. The obvious explanation is that the participants were better able to predict these terminal words based on the earlier part of the formulaic sequences. Ehrlich and Rayner's (1981) participants fixated words that were predicted by the preceding context less often and more quickly than words appearing in neutral contexts, and it seems that the context provide by a formulaic sequence itself is enough to facilitate the processing of the terminating word of that sequence.

This is largely consistent with the view that such sequences are stored and processed as wholes. Once a sequence is recognized, there should be less need to sample the end of the sequence, simply because the person already knows what that ending is. It could be argued, however, that if formulaic sequences are processed as wholes, there would be no need to sample the ends, leading to the expectation that subsequent fixations would be beyond the terminal word. We did not find this, with terminal words drawing fixations in the majority of cases. It may be that the mind still fixates on terminal words, albeit briefly, as a kind of check in case the word string appears to be a formulaic sequence, but is in fact not. Let's take the sequence *black sheep of the family f*or example. It occurs eight times in the British National Corpus, but similar strings *black sheep of the financial world, black sheep of the independent sector, black sheep of the industry* each appear once. Thus, the string *black sheep of* usually predicts *the family*, but the mind must allow for the creative use of language, where these formulaic sequences are manipulated for effect, precisely because it can be assumed that people know the original form. It should be stressed however, that when we looked at the corpus evidence for the formulaic sequences in this study, they were almost exclusively used in the their original forms, which reinforces the predictive power of the beginning segments of formulaic sequences.

Another possible explanation for why the terminal words were fixated is that the mechanism controlling the reader's fixations is unable to advance the saccade accurately enough to skip the complete sequence, even though this would be most efficient. This would suggest that skipping is not determined by contextual predictability. Current models of eye guidance during reading also propose that decisions to skip words are informed by the extraction of visual information about words that are not currently fixated. The E-Z Reader model of eye guidance will be discussed in more detail later in this section.

It is interesting to note that the nonnatives also had fewer fixations on the terminal words when in a sequence. Although they needed more fixations than the natives on average, they still seemed to require fewer fixations at the end of a formulaic sequence than in the middle of a nonformulaic text. In other words, even though nonnatives were not as proficient at reading as the natives, the nonnatives still demonstrated the same type of processing advantage when it came to terminal words. However, this advantage only held in terms of number of fixations, not in terms of the duration of fixation. Although they needed fewer fixations of the terminal words in sequences, they needed to look at these words just as long when in sequences as when not in sequences. The natives, on the other hand, required a much shorter gaze when the terminal words were in sequence than when not.

Given the current state of knowledge regarding the processing of formulaic sequences, it is difficult to explain why the nonnatives required fewer fixations but an equally long gaze time for terminal words in sequences. We could speculate that mastering the recognition of formulaic sequences in written texts is an incremental process, and early partial mastery is rewarded mainly by not needing to fixate on the vocabulary in a text as much, but it is only with fuller mastery that the requirement for a "full duration" fixation lessens.

This problem of a dissociation between the number of fixations and the duration of those fixations, seen in the reading of the non-native speakers, can be resolved by considering a current theory of eye movement control in skilled readers. The E-Z Reader model proposed by Reichle, Pollatsek, Fisher & Rayner (1998) is an account of where readers look, and for how long, and takes account of a range of behaviours (see also updated versions of the model by Reichle, Rayner & Pollatsek, 1999, 2003, and by Rayner, Reichle & Pollatsek, 2000). For example, the longer fixations on uncommon words, the skipping of highly predictable words, the 'spill-over' of processing from one word to the next, and longer saccades into longer words, are all predicted by the E-Z Reader model, which has been tested against the recorded eye movements of adult readers. To see how the model can account for our non-natives showing sensitivity to the appearance of a terminal word in a formulaic sequence in their fixation probabilities but not in their fixation durations, we need to describe the model in a little detail.

The E-Z Reader model proposes that eye movement control is achieved through a series of processing stages, some of which influence the decision about *where* to move next, and some influence the decision about *when* to move our eyes. These processes are as follows:

1. **Familiarity Check.** In this stage a newly fixated word is assessed for its familiarity, determined mainly by the word's frequency of occurrence in the language. Unfamiliar words will take longer here, and this is the first point at which word frequency will influence fixation duration. This is the frequency given by a word corpus such as the one used in the present experiment, al-

though it must be recognised that a word corpus is an estimate and is an average for a population. Individuals within the population will have their own lexicon, in which each word will have its own frequency. This frequency will reflect the reader's own personal interests and domain of expertise. It will also change on a daily basis, as words are encountered. (Consider, for example the subjective frequency of the generally infrequent word *metatarsal* for a fan of English football at the start of the 2002 World Cup, when one of their favourite players broke this bone.) The predictability of the word, as determined by its context, will also influence this assessment.

2. **Lexical Access.** In this stage the word is recognised in that its lexical representation is contacted by the visual input, and the word becomes available for whatever syntactic and semantic processing the reader requires. The word's frequency and context will influence the ease of lexical access, as with the Familiarity Check. These two processes together constitute the word recognition system, and are separated so that once familiarity is determined and indicative of imminent recognition (but before the full lexical access is achieved), a signal can be sent to the oculomotor system is start programming the next saccadic eye movement. The major advantage of separating the Familiarity Check from Lexical Access is that this decouples the signal to program a saccade from the signal to shift attention. In turn, this allows the model to explain 'spill-over effects' whereby processing of a difficult word continues to have an influence when the reader's eyes have moved to the next word (Word$_{N+1}$). If the reader's eyes can move before lexical access is completed, then any residual lexical activity would be apparent when the next word was being fixated.
3. **Early Saccadic Programming.** The first stage of saccadic programming is said to be labile, in that it can be modified by information that is collected before this stage is completed. During this labile stage of processing the following sequence is possible. A decision can be made to move to the next word following completion of the Familiarity Check; attention then moves to the next word and a Familiarity Check on that word establishes that it is very familiar; and at this point the saccade to that word can be cancelled. This early extraction of visual information from the next word can result in skipping, but only if this stage of saccadic programming is labile can the movement be cancelled, to allow the reader to skip the fixation on the next word (Word$_{N+1}$).
4. **Late Saccadic Programming.** During the course of programming a saccadic movement a threshold is reached after which programming is no longer la-

bile, and the saccade will be executed. At this point the saccadic movement is obligatory, and will be executed upon completion of programming.

5. **Saccadic Movement.** Saccades are usually regarded as ballistic movements, in that once initiated they cannot be modified. The eyes are projected towards a target just as a ball is thrown from one player on a sports field to another — once it leaves the thrower's hand the trajectory can no longer be modified by the thrower. The characteristics of saccadic movements are no longer influenced by linguistic factors once the non-labile programming stage is reached.

This powerful model of eye movement control accounts for the major phenomena observed when adults read sentences. The effects of high word frequency and high word predictability have their effects at the first two stages, by allowing them to be completed early, allowing saccadic programming to start early. The effects of word skipping are explained by recognition of the familiarity of the next word before it is fixated, at a point when saccadic programming is labile. We can now look at the processing of formulaic sequences with the E-Z Reader model, and speculate on differences between native and non-native speakers.

When a native speaker reads a formulaic sequence of words such as *I can see what you mean* or *the black sheep of the family,* the words become more predictable as they progress through the sequence, and the final word ($Word_N$) is almost redundant. The Familiarity Check would be completed earlier than for the equivalent terminal word placed in a non-formulaic text, thereby allowing faster word recognition overall. This has two consequences. Because the final word in the sequence is recognised early, the signal to begin the saccadic programme is started early, and so the reader's eyes fixate the target word for less time than otherwise. This is the reduced fixation duration on final words than upon the same words in non-formulaic sequences (0.71 fixations per word *vs.* 0.86 fixation per word). When looking at the penultimate word in a sequence ($Word_{N-1}$) the Familiarity Check would allow the reader to ascertain that the sequence is predictive and the words familiar, and attention would move to the final word ($Word_N$). The Familiarity Check on this word, performed while the reader's eyes remain on $Word_{N-1}$, would also conclude that the word is familiar. If this Check on $Word_N$ (the target word) is completed during the labile Early Saccadic Programming stage, then a decision can be reached to skip the target word. Not all target words were fixated by the native speakers, and so we can conclude that the Familiarity Check did indeed enable the skipping decision to be made.

The non-native speakers had longer fixation durations overall when reading the passages, suggesting that their personal frequencies of the words being shown were not as high as those of the native speakers. This is a product of their lifetime's exposure to these words. When a non-native speaker encountered a formulaic sequence, the pattern of fixations was slightly different to the pattern seen in native speakers. Whereas they did not show an effect of predictability on fixation duration, they did show an effect on the number of fixations. The effect of predictability upon fixation probability may be a product of a relatively slow Familiarity Check resulting in an intra-word saccade (see Rayner, Reichle & Pollatsek, 2000). There were 1.46 fixations on each target word not in a sequence, in contrast with 1.37 fixations for the same words in formulaic sequences, but note that in both cases there is more than one fixation per word. These words received multiple fixations, and the average over all words was 1.40 fixations per word for non-native speakers. Their tendency was to fixate, and then sometimes refixate. There was moderation of this decision, with a greater probability of refixation when the final word ($Word_N$) was not read in the predictive context of a formulaic sequence. Information about the word, collected during the word recognition stages, was used to influence the decision as to whether to make an intra-word or inter-word saccade, but this did not influence the duration of fixation on $Word_N$. For the non-native speakers, each word was fixated, on average, more than once, but, as can be seen in Figure 2, these multiple fixations consisted of refixations (i.e., making another fixation on the word before making a movement to the next word) and regressive fixations (i.e., returning to a word after reading other words). The multiple fixations of non-native speakers varied according to whether the target word completed a formulaic sequence or appeared in a neutral context, but their durations did not vary. The E-Z Reader model does not offer a specific explanation for this pattern, which suggests that the processing of formulaic sequences varies as a result of post-recognition processes. Recognition of the target word did not vary, but decisions about where to fixate next did show sensitivity to these phrases. Why might the non-native speakers choose to refixate or regress to the final word of a formulaic sequence? The present study does not provide an answer, but does suggest that the decision to do so occurs after all of the words in the sequence have been recognised, and therefore may result from uncertainty or lack of confidence in their comprehension.

An issue we did not directly address in this study is whether the nonnatives actually knew the formulaic sequences or not. We know from the selection criteria that the natives were very likely to know all or almost all of the formulaic sequences, but this may not hold true for all of the nonnatives. When we tried to follow this up, only six of the nonnative participants were available. A Dutch and a German participant knew 17 and 20 sequences respectively, but three Chinese speakers (more representative of the nonnative group) knew 9, 10, and 12. A Japanese participant knew 10 out of the 20 sequences. Overall, it appears for many of the nonnatives, a considerable number of the formulaic sequences were unknown. Still, the nonnatives did show an advantage for the terminal words in the formulaic sequences, which may indicate partial knowledge of the target sequences, but knowledge which had not reached the level to where participants could consciously define the sequences. The issue of partial knowledge is an intriguing one which could be usefully explored in future research.

Conclusion

This study has applied the eye movement research paradigm from psychology to explore the question of how formulaic sequences are processed. We now have evidence that the terminal words in formulaic sequences are processed more quickly than the same words when in nonformulaic contexts. This provides evidence for the position that formulaic sequences are stored and processed holistically. But there are still many questions regarding the exact nature of the processing, for example, why the nonnatives were found to use fewer, but not shorter, fixations of the terminal words. Another issue is how the words in a formulaic sequence relate to each other in terms of processing. This study showed the value of eye-movement methodology in exploring the terminal word of formulaic sequences, but could not investigate each word in a sequence, simply because natives in particular do not sample all words in a text. Another methodology is required which can explore the processing of formulaic sequences in a word-by-word manner. Schmitt and Underwood (this volume) use a self-paced reading methodology in an attempt to do this. Given the widely recognized importance of formulaic sequences, it is now time to use all of the tools available in the psycholinguistic toolkit to investigate these items.

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Appendix

Experimental stimuli

Note: In the passages below, the target formulaic sequences are in *italics* and the control words in **bold** for the reader's convenience. In the actual experiment, these lexical items were unmarked.

Welcome to the experiment!

In this experiment you will be required to read brief passages of text in preparation for a simple comprehension question. When you have finished reading each passage, press either the left or right arrow key. A question will then appear about the previous passage. The answer will either be 'yes' or 'no'. Press the right arrow key ⇒ for 'yes'. Press the left arrow key ⇐ for 'no'.

First there is a practice passage to get you used to the experiment. Press either key when you are ready to start.

My friend Peter always insists that I go out with him to the pub at lunchtime, but I prefer to stay at my desk working. It's a real problem to me, because I value his friendship and I don't want to upset him by refusing to go out. If only he would ask my opinion occasionally then I would be able to say what I really think.

Q: Am I happy to go along with Peter's plans?
Press ⇐ for No
Press ⇒ for Yes

Press either arrow key when you are ready to start the real experiment.

Dave had been out at parties all weekend and did no work at all on his course assignment, even though it was due at the beginning of the week. But then he worked really hard on Monday and met the deadline *by the skin of his teeth* before the office closed on Tuesday afternoon. Dave had almost **nine** days to write the essay but as usual he did it all at the last moment.

Question 1: Did Dave hand his essay in on time?
(Answer Yes)

Sam always seemed to leave things until he couldn't put them off any longer. Sometimes this got him into real trouble. His dentist had warned him about having his **teeth** looked at regularly but Sam did not visit him again until he had a bad toothache. After that terrible experience, Sam realized that *a stitch in time saves nine* and decided to visit his dentist every six months.

Question2: Has Sam always visited the dentist regularly?
(Answer No)

You've been talking in circles for 30 minutes trying to tell me something. Please don't *beat around the bush* for another half an hour, but just get to the point and tell me! If it was you who dropped my flower **basket**, don't worry because I won't be angry with you.

Question 3: Did someone drop the flower basket?
(Answer Yes)

Dave had been out having a good time all semester and now exams are coming and he is not prepared. He'll have to *keep his nose to the grindstone* in order to pass them. It seems that his **policy** of leaving things until the last minute means that he's going to have to miss Sam's party.

Question 4: Is Dave prepared for his exams?
(Answer No)

Your financial adviser gave you bad advice when he insisted that you put all of your money into high-technology stocks, and now they are worth nothing. I told you not to *put all your eggs in one basket*. You should have spread your money into many different kinds of investment. And now that you have hurt your **back** in the car accident, you will need all of the money you can get.

Question 5: Were you advised to invest in high-technology stocks?
(Answer Yes)

You've been putting off taking your driving test for weeks because you are afraid. You need to just *take the bull by the horns* and do it anyway. I'm sure you'll pass it easily and in a **short** time you'll be driving yourself all over town.

Question 6: Have you taken your driving test?
(Answer No)

Joe said that there are a lot of factors that cause unemployment in the UK that you should be clear about. The cost of factories and equipment is high here, labour costs less overseas, and the pound is currently very strong in comparison to other currencies. Jill said "Okay, *I see what you mean* that unemployment is so complex that it can't be blamed on one thing, but you're missing the human element, because the effect of unemployment on a **family** can be tragic."

Question 7: Does Joe think unemployment is caused by many factors?
(Answer Yes)

Cindy was always getting herself into trouble, and was back into difficulties again. It was going to be hard to tell her mother that that she had lied to her about throwing a **stone** through the kitchen window, but she knew that her mother would find out eventually. So as usual *honesty is the best policy* and Cindy was just going to have to tell the truth.

Question 8: Was Cindy going to lie again?
(Answer No)

Kate checked whether Alice had a lot of things to do at the garden centre today. Alice replied that she did, mainly buying some flowers and a new **bush** for the front garden and said that *as a matter of fact*, she was leaving for the garden centre right that minute.

Question 9: Was Alice going to the garden centre?
(Answer Yes)

I can't make up my mind what to do, but it's a well-known **fact** that I'm indecisive. I'd like to buy a new coat for the winter but *on the other hand* I need to save money for the rent. I can't decide which is more important.

Question 10: Would this person like to buy new boots for winter?
(Answer No)

I went home last weekend and went out dancing with my old friends. We had a great time, but spent all of our money, and had to walk 10 miles in the rain to get home. Carrying one of my friends home almost broke my **back** but it was fun to be with them again. The roads were getting flooded and at one time I thought that we were going to sink into the mud. But *to cut a long story short* we eventually got home soaking wet at 3:30 am.

Question 11: Did they have to walk home?
(Answer Yes)

Bob and Jane were loading the car for a camping trip. They love being out in the clean **air** away from the dirt in the city. Bob wanted to take just a tent and sleeping bags, but Jane wanted to be more comfortable. So she put extra blankets, pots, pans, books, lights, extra clothes, a chair, and many other things into the car. When Bob saw this he was surprised and said, "You're taking too much stuff! You have *everything but the kitchen sink* packed into the car and I'm not sure that there's room for me!"

Question 12: Did Jane pack the bare minimum?
(Answer No)

It was bad enough that Helen was always late for basketball practice and that she was always complaining. But when she missed the big game without telling us, that was *the straw that broke the camel's back* and so we all agreed she had to be dropped from the team. But it turned out that Helen had burnt her **hand** badly on a pot and couldn't have come to the game, so we all felt very bad about wanting to drop her.

Question 13: Did Helen burn her hand?
(Answer Yes)

Bob thought that their camping trip really was in trouble. It was the middle of the night, the rainstorm was getting worse, the **lining** of the tent was ripped, and the car was out of petrol. To top it off, their cell phone batteries were dead! Jane agreed and said that she thought that they were really *up the creek without a paddle* and in desperate need of help.

Question 14: Was the camping trip going well?
(Answer No)

I really enjoyed my holiday at the old windmill. It was in full working order with the original **grindstone** and everything. It was such a change after the hard work at the university. After reading only really difficult books all semester, it was like *a breath of fresh air* to relax at the mill and enjoy reading an easy novel.

Question 15: Did this person enjoy their holiday?
(Answer Yes)

I was sick all last week and couldn't go out. I was due to visit my friends and that had to be called off. But at least I caught up with all of my homework, so *every cloud has a silver lining* and now I'm back on schedule. I was so ill that I couldn't do any cleaning and I had to leave the dirty pots in the **sink** for five days, but I think the kitchen's looking organised now.

Question 16: Did this person do the cleaning while they were ill?
(Answer No)

My brother Ron is always doing crazy things. First he went to Africa and lived in the jungle for a year with some hunters. He got deported when he was found with some **horns** from rare animals. Then he got in trouble for stealing clothes from a store. Now he's decided to hug every tree in the UK. But my parents and I have come to expect odd behaviour. He definitely is *the black sheep of the family* although we still love to have him around.

Question 17: Did Ron live in Africa?
(Answer Yes)

I wouldn't worry about your canoe race with James. He's slow and not very strong. In fact, I'm sure you could beat him *with one hand tied behind your back* if you just remember to concentrate on your **paddle** technique and work hard over the whole course.

Question 18: Is James a fast canoeist?
(Answer No)

Jim thought that the main reason they received a poor mark on their group project was that they didn't allow enough time to do it properly. Being short on time will always **mean** that the final product is less than satisfactory. Sally agreed and thought that he'd *hit the nail on the head*; if they had another week, they could have done much better. They missed a lot of important information by having to rush it.

Question 19: Did Jim and Sally rush their project?
(Answer Yes)

By going home to London last weekend, John was able to both study at the British Library and to attend his mother's 50th birthday party. He was quite pleased with himself, as he always liked *to kill two birds with one stone* when he could. The only downside to his visit was that he picked up a terrible cold in his **head** and had to take time off work to recover.

Question 20: Did John miss his mother's birthday party?
(Answer No).