University of Southampton

Faculty of Social and Human Sciences

Doctorate in Educational Psychology Programme

The Contribution of Phonological Access towards Syntactic and Semantic Sentence Processing: Eye Movement Evidence from Arabic

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Doctorate in Educational Psychology (DEdPsy)

June 2012

Resubmission August 2012

(Word Count: 20,308)

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

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The relevance and importance of phonological access and of teaching phonology has sparked numerous professional and academic debates. The views of educators and academics have recently returned to emphasising the importance of phonology, but current directions in teaching practice and academic investigation offer limited understanding of the role of phonology in natural reading. Basically, as evident in current models of reading development, phonology remains thought of as a developmental milestone. What is lacking is a detailed understanding of how phonology is used in skilled natural reading and how phonological access interacts with other cognitive processes in text reading. In the first chapter I discuss how systematic investigations using Semitic languages (e.g. Arabic) can allow us to address this gap in our knowledge. Furthermore, I argue, with extensive evidence, that research which utilises eye-tracking methodology provides the most comprehensive way to exploring the cognitive processes of natural reading, including potential interactions of phonological and syntactic and semantic processing. In the second chapter I present an empirical investigation in which I tracked the eyes of native readers of Arabic during natural reading. Through presenting participants with well-designed and ecologically-verified stimuli, our research team uncovered evidence that skilled readers use phonology strategically when processing syntax and semantics. The findings of our investigation has clear educational implications which transcend the particular language used in the investigation (i.e. Arabic). This investigation makes a significant contribution towards developing a comprehensive understanding of human language-processing universals by including evidence obtained from non-Roman alphabetical language.

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Declaration Of Authorship

I, Ehab W Hermena

declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

The Contribution of Phonological Access towards Syntactic and Semantic Sentence Processing: Eye Movement Evidence from Arabic

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;

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Acknowledgements

I would like to thank Dr Sam Hellmuth (The University of York) for her support in norming the experimental stimuli and her crucial input in the planning phases of this research. I would like to thank Gemma Fitzsimmons for all her help in programming the experiment and in starting the analyses. I would also like to thank our participants for their support and enthusiasm. Finally, I would like to thank both my supervisors, Prof Simon Liversedge and Dr Denis Drieghe for their tireless support, enthusiasm, and encouragement.

Chapter 1

Towards Better Understanding of the Role of Phonological Access in Sentence Processing: Eye Movement Research and Potential Contributions of Studying Reading in Semitic Languages

1.1 Abstract

The teaching of reading has moved from an emphasis on phonological instruction, to considering phonology irrelevant, and back again into emphasising the role of phonology in reading development. Indeed, all models of reading development agree that mastering the alphabetic principle is a key milestone in children's literacy development. However, our understanding of the role of phonological access remains narrow and limited to its role in development. Moreover, our understanding of possible interactions of phonological access with semantic (meaning) and syntactic (grammar) processing during natural and skilled reading remains very basic. This perhaps can be explained by the limitations that exclusively studying Roman alphabetic languages impose on researchers. We argue that using Semitic languages (e.g. Arabic) as an investigation medium may allow researchers to address this gap. We further argue and explore extensive evidence which illustrates that research utilising the methodology of tracking eye movements is most informative when investigating the online, or uninterrupted, cognitive processes associated with reading. The benefits of studying phonological processing in a language like Arabic, using eye movement research methodology will be highlighted. Furthermore, the potential role of applied psychologists in the field of education in carrying out this type of research to further our knowledge will be discussed.

1.2 Introduction

This discussion begins by exploring the role of phonological processing in the development of reading and literacy skills as portrayed in empirical investigations and in models of reading development. The discussion will be critical and will highlight the limitations and caveats of investigation tasks which place processing demands on the cognitive system which are different to those associated with natural reading. Current gaps in our understanding of the role phonological access plays in skilled (as opposed to only developing) readers will be highlighted, and a way forward to addressing this gap will be suggested. Namely, studying the phonological processing of skilled readers in other alphabetic languages (e.g. Arabic) will be suggested as a method which would allow for investigating phonological access in precisely the way required to address the gap in our knowledge. The properties of Arabic which makes it an ideal candidate for carrying out this research will be highlighted.

Having explored the shortcomings of experimental tasks which do not resemble, and which actually interrupt, natural reading, the discussion will then turn to exploring how and why tracking eye movements can be used to learn more about the cognitive processes of natural reading. The empirical works selected for this discussion are limited to seminal and current works where researchers have clearly demonstrated adequate experimental control, have used natural reading tasks (unless otherwise stated), and disseminated their findings in peer-reviewed publications. The discussion includes evidence detailing the relationship between word and text properties (including phonological properties), readers-related factors (e.g. skill level) and the tight link between these and the recorded patterns of readers' eye movements. In doing so, it is hoped that the non-expert reader will become more familiar with the concepts, questions, and standards of carrying out eye movement investigations in reading. It will also become clear that eye movement research allows for the most ecologically valid exploration and most detailed understanding of the cognitive processes associated with reading, including our question regarding the role of phonological access in facilitating semantic and syntactic processing. It is important to highlight at this stage that the discussion of eye movement evidence is targeted at applied psychologists and thus, by necessity, is elementary in the sense that it does not explore the numerous theoretical and technical issues and questions relating to eye movement research which are of more interest to academics.

Conclusions will then be presented highlighting that addressing our current gaps in fully understanding the role of phonological access can best be achieved through eye movement investigations of other alphabetic languages (such as Arabic) to complement what we already know from studying Roman alphabetic languages (e.g. English). Furthermore, the relevance of these findings to the field of education will be detailed, and a vision for future educational research into literacy acquisition and interventions, and the role of educational psychologists (and trainees) is also briefly discussed.

1.3 Phonological Readiness in Reading Development and Phonological Access in Natural Reading: Current Knowledge and Limitations

The question about how to teach reading, and the role of phonological instruction in teaching reading is over a century old (e.g. Huey, 1908/1979). Predominant, and overzealous, phonological teaching programmes which added marks on top of letters, particularly vowels, to disambiguate their pronunciation, and other programmes which used phonological symbols (phonograms) and non-traditional spellings to regularise English letter-sound relationships (e.g. McGuffey, 1879) were later seen as irrelevant, repetitive and boring for children (Goodman, 1967; Routman, 1991; Smith, 1973; 2004). This change was somewhat fuelled by the advent of Gestalt psychology and with preliminary, and misinterpreted, findings about *word superiority effect* (Cattell, 1886; Reicher, 1969) whereby the *whole* word was seen as the main unit for reading, not the single sound. Thus, erroneously, teaching letter sounds was seen as an irrelevant exercise. However, in the light of more rigorous research and interpretations, formalised into models of reading development (e.g. Ehri, 1998; 2002; 2005; Frith, 1985; Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; Seymour & Duncan, 2001; see also Rayner, Pollatsek, Ashby, & Clifton, 2012), it is now widely accepted that children's reading development depends, for a large part, on mastering the phonological knowledge of letter-sound correspondences. Beginning to master this knowledge marks children's transition into competent reading of novel words and becoming more independent readers (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001; 2002; Rayner et al., 2012).

Identifying whole words visually from memory may serve a child with a limited number of words which look sufficiently distinct. However, as children encounter more words, and particularly words which look similar (e.g. *fine*, *dine*, *mine*), letter-sound knowledge becomes important in accessing and distinguishing these words—a task beyond the inevitable limitations of relying solely on visual memory (Metsala & Walley, 1998; Walley, 1993). Evidence clearly shows that readers do rely on the phonological representations of the words they are reading. For instance, seminal investigations (Van Orden, 1987; Van Orden, Johnston, & Hale, 1988) found that when readers were asked "is it a flower?" and then shown the word *rows*, they were highly likely to respond *yes*, indicating access to the (homophonic) phonological representation of the word which is identical to the correct word *rose*. The same was found with pseudo-words: when asked "is it an item of clothing?" and shown the letter string *sute*, readers were more likely to respond in the affirmative. Indeed, as Rayner et al. (2012; also Beck, 2006) point out, young readers who memorise whole words and appear to read confidently without laborious sounding out in early reading development are more likely to flounder when they encounter novel words which are long and similar, where decoding phonological details is essential. Longitudinal evidence also shows that pre-schoolers with strong awareness and knowledge of letter-sound correspondences are more likely to develop as fluent readers (Lonigan, Burgess, Anthony, 2000; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Storch & Whitehurst, 2002). Furthermore, difficulties in acquiring, mastering, and applying phonological knowledge are linked with developmental reading difficulties including dyslexia (see e.g. Harm & Seidenberg, 1999; Lavidor, Johnston, & Snowling, 2006; Snowling, 2000; Snowling, Duff, Petrou, & Schiffeldrin, 2011; Snowling & Göbel, 2011; Vullutino & Fletcher, 2005). Additionally, large-scale investigations showed that teaching which explicitly and systematically focuses on letter-sound knowledge to *all* children serves to reduce the incidence of reading difficulties (Bos, Mather, Dickinson, Podhajski, & Chard, 2001; Ehri, Nunes, Stahl, & Willows, 2001; Foorman et al., 1998).

Currently influential models of reading development (see Ehri, 2005) typically describe the progression of children in dealing with written words in terms of phases. These begin with an early stage (around 5 years) where children guess at words using minimal visual clues (e.g. including accompanying pictures, Frith, 1985; Gough, 1993). Readers then begin to acquire the alphabetic principle, or the knowledge that the letters of the word are relevant to its pronunciation, and begin to learn the letter-sound correspondences. Readers are said to progress from early- to partial- to full-alphabetic stage as they learn more letter-sound correspondences and become increasingly able to deploy this knowledge in decoding, and learning, new words (Ehri, 2005). The final stage of development is typically characterised by the confidence and readiness of the reader to resort to phonology knowledge to *attack* new words, while through over-learning and repetition of exposure, other words become identifiable holistically[1]. Less effortful decoding allows children's cognitive resources to be allocated to text comprehension whereas in earlier stages they are mainly consumed in decoding the text (Beck, 1998; Rayner et al., 2012).

What all models (stage-like and continuous development, see Footnote 1) agree on, is that mastering phonology underpins the ability to decode novel words, thus allowing the readers to progress in reading beyond what is possible for instruction which only targets visual memorisation of whole words (Cunningham, Perry, Stanovich, & Share, 2002; Ehri, 2002; Share & Stanovich, 1995). Share (1995; 1999; also Cunningham et al., 2002; Kyte & Johnson, 2006), with findings from Hebrew and English, explained this assumption further through disseminating the *self-teaching* model of literacy development. Essentially, sounding out and reading aloud novel words using existing phonological knowledge reinforces the orthographic learning of these words. For instance, Kyte and Johnson comparing two groups of pupils (about 10-year olds) on orthographic learning tasks (e.g. identification from amongst distractors, spelling, and speed-naming), found that the pupils who were allowed to apply their phonological knowledge in sounding out and reading aloud the novel words, outperformed pupils who only looked at the novel words or were not allowed to sound them out and read them aloud. The self-teaching model thus

[1] Other models however suggest that development does not happen in stages; rather, it takes place in small continuous increments. Essentially, the change in behaviour from minimal visual recognition to fluent reading of known and novel words comes about through learning, abstracting knowledge from many examples, and repetition (e.g. Munakata, McClelland, Johnson, & Siegler, 1997; Perfetti, 1992). Indeed, while conceptualising development in terms of discrete stages provides useful heuristics which makes understanding and describing the observed changes in children's reading easier, it is important to remember that, as yet, we have no empirical evidence that development comes about in discrete stages. Furthermore, theorists putting forward stage-models (e.g. Frith, 1985) readily acknowledge that these stages may not be mutually exclusive.

considers reading texts containing a small but sufficient proportion of unfamiliar words to be very effective in getting the learner to rehearse, consolidate, and apply their phonological knowledge while simultaneously increasing their vocabulary knowledge. Another tenant of this model, with clear implications to educators, is that automaticity is a characteristic of certain words, not readers, and that readers' improve automaticity through extensive reading practice.

Grasping the alphabetic principle and achieving mastery of phonological knowledge does not happen at a similar rate for all learners, or for all languages (e.g. Share, 2008; Ziegler & Goswami, 2005). As mentioned above, widely-accepted research findings consistently show that this is an area of difficulty for children who experience reading difficulties, and who seem to lag behind their peers in learning letter-sound correspondences and in applying this knowledge in reading fluently, and in expanding their vocabulary knowledge (Hulme & Snowling, 2009; Snowling, 1998; 2000). On the other hand, in languages where letter-sound correspondences are transparent, that is, where a single letter represents a single sound, regularly and consistently, such as in Spanish, German, Finnish and Italian, children excel in applying the letter-sound correspondence rules in reading novel and nonsense words (Seymour, Aro, & Erskine, 2003). This happens from an earlier age (Aro & Wimmer, 2003; Wimmer & Goswami, 1994), even when socio-economic and cultural factors are controlled for (Bruck, Genesee, & Caravolas, 1997; Ellis & Hooper, 2001), compared to readers of less regular orthographies like English. Furthermore, reading difficulties are less prevalent in learners of orthographically-transparent languages (Seymour, 2005). The opacity of English orthography comes from the prevalence of the many-to-one and one-to-many letter-sound correspondences, where a single sound can be represented by many letters, or letter combinations (e.g. the long /i/ in *bite*, *fly*; the sound /er/ in *slur*, *stir*, *her* etc.) and where the same letters, or letter combinations can produce multiple sounds (e.g. the different sounds of /a/ in *nature* and *natural*; /oo/ in *book*, *groom*; /ow/ in *low*, *now*, etc).

Beyond these accounts of how phonological knowledge mediates reading development, our understanding of the role of phonology in natural skilled reading remains very basic. Specifically, our understanding of how phonological access interacts with or facilitates syntax (grammar) and semantics (meaning) processing in natural skilled reading is still largely limited to the above-mentioned account concerning the allocation of cognitive resources (e.g. Rayner et al., 2001). Questions like how accurate (or inaccurate) phonological access facilitates (or disrupts) access to verb tense (syntax) and sentence comprehension (semantics) are still thought of in binary terms: correct or incorrect decoding. This binary outlook precludes real understanding of the nature, time course, and consequences of potential disturbance and of the cognitive processes readers perform to recover from such disturbance. These are questions relevant to language processing in all languages, and of particular interest to learners and educators. Understanding the magnitude of such disturbances, and examining how readers recover has direct implications for teaching situations where pupils may make phonological processing errors which impact upon their reading comprehension performance, and ultimately on reading enjoyment.

From an educational standpoint, this basic understanding of the role of phonology as merely a milestone for early reading development is unsatisfactory given that evidence show that phonological processing difficulties may persist into adolescence and adulthood and impact upon reading performance (Wolff, 2009; Zabell & Everatt, 2002). Other evidence suggest that phonological and syntactic processing can predict reading comprehension performance in secondary age pupils (e.g. Holsgrove & Garton, 2006). We, however, lack precise understanding of the nature and time course of the interactions between phonology and other textual properties (e.g. semantics and syntax) during reading. This knowledge should be the source for informing educators as to how pupils from this age group can be supported in coping with the reading difficulties resulting from problematic phonological processing (e.g. breakdowns in semantic or syntactic processing). This is particularly important given that in secondary education: (a) curriculum time does not allow for extensive phonological instruction, (b) phonological instruction may feel childish and uninteresting, and so pupil and staff preferences may shift towards less systematic interventions, and (c) in some cases phonological instruction may take long time to produce tangible results in terms of the overall text reading fluency and accuracy, putting both academic success and the learners' self-esteem at risk (see e.g. Lingard, 1997; Shankweiler, Lundquist, Dryer, & Dickinson, 1996).

Studying pure phonological access and its impact on syntactic and semantic processing, however, is hard to carry out in languages such as English. For instance, researchers may add or delete phonological segments (e.g. /*ed*/) to change the pronunciation of a verb and to examine the resulting change in its syntactic value (e.g. from present to past tense). However adding or removing the sound segment /*ed*/

changes the morphology (*ed* is an additional suffix) and the orthography (the word will look different) of the printed word and thus examining the effect of pure phonological access on semantic and syntactic processing without orthographic or morphemic confounds can scarcely be carried out. Examining the role of phonological processing on more complex syntactic sentence features (e.g. changes from active to passive) is even less possible given the required sentential changes which would lead to introducing more confounds (e.g. changing *defeated* to *was defeated*; *wrote* to *was written*; etc.). Thus, using English and other Roman alphabetic languages to investigate the role of phonological access in facilitating semantic and syntactic processing may not further our understanding beyond the binary outlook. Studying readers of other world languages, like Arabic and Hebrew may further our understanding of these issues, as will be argued below.

Before turning to these other world languages and discussing how their properties can allow methodical investigations of the question posed above, it is important to make the following point. In the view of the present author (see also Lupker, 2005), any successful word identification models need to account for semantic processing of the word itself, as well as the impact of the semantic context within which the word is encountered. Essentially, the word's orthographic, phonological and semantic properties interact, allowing for word recognition and access, and these properties also interact with the sentential properties—the syntactic sequence in which this target word fits. Put more simply, for the target word DOG in the sentence:

(1) The boy was chased by the angry dog.

the interacting word and sentence features include (a) the orthographic features of the word—a 3 letter word D-O-G; (b) the sound units making up the phonological representation of this word /d/ /o/ /g/; (c) the word meaning; (d) its place in a syntactic sequence which indicates that the sentence is passive and that the dog was 'doing the chasing'; and (e) the sentence meaning whereby it is deemed plausible for the word DOG to appear in this particular location of the sentence (compared to, for instance, the word STATUE, even though statues may look angry!). All these word and sentential properties interact and their interaction needs to be accounted for in comprehensive models of reading.

This interaction can be seen clearly in a language like Arabic (and Hebrew). A word's pronunciation (phonology) is closely linked to its syntactic (grammatical) status and semantic representation (meaning). This becomes an acute issue as, similar to Hebrew; Arabic contains a large number of orthographically identical words (homographs—words which contain the same letters in the same order). For instance the letter string كتب /ktb/ can mean *books* (noun), *he wrote* (active, past tense), or *was written* (passive, past tense), depending on its pronunciation (Abu-Rabia, 2001; Ravid & Shlesinger, 2001). As described above, this contrasts with English. Thus, arguably, studying Arabic phonology allows for studying the interaction between phonology, semantics and syntax on a level which is not possible in other alphabetic languages (e.g. English, German, etc.).

How do Arabic readers access a word's phonological representation? Arabic is a predominantly consonantal writing system, that is, most words are made up from 2-4 consonant roots (e.g. كتب /ktb/). These consonant roots need to be vowelised to produce the correct word pronunciation (Abu-Rabia, 2007; similar to Hebrew, e.g. Schiff & Ravid, 2007). In addition to 3 vowel sounds written as letters (roughly equivalent to /a/, /o/ and /i/), a system of auxiliary signs, or diacritical marks (hereafter diacritics), exists in Arabic and maybe placed above or below the letters in a word, thus pointing the reader to a certain pronunciation which matches the semantic requirements and grammatical position of the word (Abu-Rabia, 2002; Haywood & Nahmad, 1965; Schulz, 2004). For instance, using the example كتب /ktb/ may mean *books* if pronounced as كُتُبْ /k^{o}t^{o}b/, *was written* if pronounced as كُتِبَ /k^{o}t^{i}b^{a}/, and *he wrote* if pronounced كَتَبَ /k^{a}t^{a}b^{a}/, with diacritics marked as superscript for illustration.

For a reader of Arabic, looking at an undiacritised single word is somewhat analogous to an English learner or a child with reading difficulty looking at the word *wind* but not being sure whether to pronounce it to rhyme with *pinned* or with *find*. The main difference with Arabic words is that the same letter string is likely to have more than 2 possible pronunciations (vowelisations), depending on how each consonant is vowelised, and with the change in vowelisations (pronunciation/phonology), the word's semantic and syntactic values are altered as illustrated above. In text reading, comprehension becomes at stake. However, skilled adult Arabic readers are typically exposed to non-diacritised texts and they rely heavily on sentence meaning (semantics) and grammar knowledge (syntax) to disambiguate the pronunciation of homographic words (e.g. *ktb*) in a manner analogous to when a reader of English becomes in no doubt about how to pronounce the letter-string *wind* given the meaning of the sentence. Indeed, Arabic diacritics are only printed in religious texts, poetry, and children's books (up to 9-10 years old, Abu-Rabia, 1998), and on a minority of words where ambiguity may be severe enough to impede text comprehension (Hammo, 2009; Schulz, 2004). However, a number of investigations (Abu-Rabia 1996; 1997a,b; 1998; 1999) found that young and old, skilled and poor native Arabic readers benefit from the presence of diacritics while reading single words, sentences, and different types of texts. These findings were replicated in Hebrew reading with diacritics (Share & Levin, 1999). Arabic (and Hebrew) can thus be thought of as a very apt medium for exploring phonological-semantic and phonological-syntactic interactions in natural reading. Exploring these interactions has the potential of furthering our understanding of language processing universals, by adding to the current knowledge which is largely based on over-studying English (Share, 2008).

A further limitation of some investigations, in addition to over-reliance on some languages and excluding others, is that phonological and semantic access are largely investigated in non-natural reading tasks, at a single word level, and separately, that is, without examining the links between them. This results in uncovering interesting findings, but does not unify or further our understanding of natural reading in general or the role of phonological access in particular. For instance in tasks such as word naming, findings suggested that in English and other languages (e.g. Japanese) words with multiple meanings (e.g. bank: river and financial institution) and high-imageability or concrete words (e.g. *rhino*, *prong*), have richer semantic representations (see Lupker, 2005) and are named faster than words which have one meaning (e.g. *toxin*) or words which are less concrete (e.g. *usage*, *logic*; see Gernsbacher, 1984; Gottlob, Goldinger, Stone, & Van Orden, 1999; Hino & Lupker, 1996; Hino, Lupker, & Pexman, 2002; Hino, Lupker, Sears, & Ogawa, 1998; Lichacz, Herdman, LeFevre, & Baird, 1999; Pexman, Lupker, & Hino, 2002; Rodd, 2004). The explanation typically forwarded for these findings is that the phonological representations of the first group of words (those with more-than-one, and concrete, meaning) receive multiple and stronger activation from the multiple meaning representations, thus leading to faster naming. These findings seem to hold only for words which occur less frequently in the language which, given the slowness of their processing, seem to show the largest benefits from these multiple meaning activations. In other tasks (e.g. lexical decision tasks, LDTs, or deciding whether a letter-string is a real- or a non-word) findings show that when the presented letter-string is an orthographic non-word (*drane*) but a phonological real word (i.e. similar to *drain*), the reader is challenged and his/her responses are delayed, and these so-called *homophone effects* are well-documented and widely-accepted (Ferrand & Grainger, 2003; Pexman & Lupker, 1999; Pexman, Lupker, & Jared, 2001; Pexman, Lupker, & Reggin, 2002).

Furthermore, phonological-to-semantic access was conceptualised at the single word level where phonology is seen as one of two ways to access a word's meaning. Influential models of word reading like the *Dual Route Model* (Marshall & Newcombe, 1973; Coltheart, 1978; 2005; Van Orden, Pennington, & Stone, 2001) suggest that readers either access a word's meaning directly from its orthographic representation, or they have to break it down into constituent sounds and access the word meaning indirectly via its phonological representation. Discussing the shortcomings of these models is beyond the scope of this piece; the interested reader is referred to Rayner et al. (2012) for some discussion. However, it is important to highlight that such models have little value in explaining cognitive processes and computations in natural reading of text, with their main focus being on single word identification. Furthermore, these models tend to, explicitly, prefer word identification using the whole-word (lexical) route over the phonological (sublexical) route. This preference is intuitive, but is over-simplistic and is not supported by evidence gathered from multiple disciplines of psychological research (e.g. brain imaging data, Pammer et al., 2004; Wheat, Cornelissen, Frost, & Hansen, 2010; and modelling and simulation data, e.g. Rueckl & Seidenberg, 2009) which clearly illustrate the importance of phonological processing in skilled word identification (Rayner et al., 2012).

Silent reading is indeed different from word naming and LDTs, and findings from research which utilises such tasks have little value in explaining natural reading processes where phonological, orthographic, semantic, and syntactic processing, as well as the readers' knowledge of the world (pragmatic) are involved (Rayner & Liversedge, 2011; Van Orden & Kloos, 2005). For instance, if single word naming is facilitated by multiple activations coming from the multiple meanings of ambiguous words, in silent reading, where the task is to comprehend the text, the activation of multiple meanings results in a competition and this slows and disturbs the reading processes. As will be discussed below, this is what eye movement records capture, particularly when the prior portions of the sentence do not disambiguate the intended meaning, or when the meanings associated with the word are equally frequent in the language (e.g. *quack* meaning duck-sound, or swindler, see Duffy, Morris, & Rayner, 1988; Rayner & Duffey, 1986; Sereno, O'Donnell, & Rayner, 2006). In natural reading circumstances, readers spend longer time looking at (fixating, see below) these words compared to words with single meanings. This additional fixation time reflects the extra processing being carried out by the cognitive system to disambiguate these words.

Our premises can so far be summed thus: firstly, beyond the role of acquiring phonological knowledge in reading development, we lack sophisticated knowledge of how, in adult and skilled readers, phonological processing facilitates semantic or syntactic processing in natural text reading. This may be impacting upon the quality of support which pupils, particularly those with phonological processing difficulties, receive. Secondly, the study of Semitic languages (e.g. Hebrew and Arabic) can compliment the knowledge acquired through studying English and other Roman alphabetic systems. Thirdly, studying these processes needs to use methodology which can simulate natural reading situations so that findings can be regarded as informative and ecologically valid. It is arguable that research which takes these points into consideration would be well-placed to produce findings which are relevant to both educators and academics. We believe that reading research which uses eye tracking methodology fits these requirements and it is to this type of research that this discussion now turns.

1.4 Eye Movement Research in Reading: An Overview

While reading text, human eyes have a specific repertoire of behaviours which can be recorded using eye trackers. Because of the physiological structure of human eyes, the area of vision where clarity and acuity is at its maximum is called the *fovea*, and it can be thought of as the centre of vision (the central 2° of vision, Findlay & Gilchrist, 2003; Snowden, Thompson, & Troscianko, 2006). 5° to the right and left of foveal vision is an area of reduced visual acuity, but where absorbing visual information (from text or from scenes) is possible (Findlay & Gilchrist, 2003; Snowden et al., 2006; Rayner, 1998). This area is known as the *parafovea*. The rest of the visual space outside the parafovea is known as *peripheral vision* where acuity is decreased sharply and the only way to actually see or absorb any details from the periphery is to move the eyes so that the desired area can be foveated. Moving the eyes is typically fast, and these ballistic movements are known as *saccades*. The eyes can saccade to new parts of the text, that is, moving forward, or backwards to previously fixated (or skipped) areas of the text so that skipped parts can be accessed, and previously-examined parts can be reappraised. It is estimated that about 10-15% of saccades go backward in the text as readers attempt to repair breakdowns in comprehension, with this percentage increasing if the reader is unskilled, young, or if they are attempting to read very difficult text (see Clifton & Staub, 2011; Rayner, 1998; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). Saccades typically move the eyes about 8-9 letters and take around 20-40 milliseconds (ms) during which vision is suppressed, that is, no visual information is taken or processed during a saccade, and this is why we do not perceive the visual world in what would be dazzling blurs between fixations (Findlay & Gilchrist, 2003).

To record readers' eye movements, sophisticated cameras which record eye behaviours every millisecond (i.e. a thousand times per-second) are typically used in laboratories where participants perform natural reading of text presented on a computer screen. Eye movement records of reading show that the subjective feeling that the eyes glide smoothly over text is a mere illusion: the eyes remain still, or fixate, on some words, or word-parts, for about 200-250ms (e.g. Rayner, 1998; 2009) so that these portions of the text fall on the fovea. Fixations are thus associated with absorbing the information being fixated. Not all words or word-parts are fixated: some words are skipped, particularly short ones (2-3 characters), and particularly when the reader expects to see these words in the text (Drieghe, Brysbaert, Desmet, & Debaecke, 2004; Drieghe, Desmet, & Brysbaert, 2007; Rayner, 1998; 2009). While fixating a word, preliminary processing of the upcoming word, in the parafoveal vision, begins, and this is known as *parafoveal processing* (e.g. Hyönä, 2011; Rayner, Liversedge, & White, 2006). Studying parafoveal processing became possible through using a technique which revolutionised eye tracking, called the *boundary technique* (Rayner, 1975, see Figure 1). Basically, an invisible boundary is placed in the text, and prior to the reader's eyes crossing it, a target word is replaced by a preview letter-string. This preview letter-string is manipulated to control what information about the target word is available to the reader before s/he actually fixates the target word. Once the reader's eyes cross the boundary, the preview is replaced by the target word (the reader is not aware of this change due to saccadic suppression). For instance, the researcher may show the upcoming word intact (e.g. *beach*), or replace it with a word which sounds the same (e.g. *beech*) or with one which looks the same (e.g. *bench*). Research has shown that when the reader is denied a correct preview of the upcoming word, it takes more time to process that word when it is fixated (see Rayner, 1998; 2009 for reviews). The advantage of being able to process the upcoming word, intact, or one of its features (like a letter-string with a similar sound), is known as the *preview benefit*. Such benefits are well recorded, for instance, when the readers are given a parafoveal preview which contains accurate phonological information about the actual target word (Ashby, Treiman, Kessler, & Rayner, 2006, more discussion below). Preview benefits allow the researchers to make informed inferences about what information the readers are processing (like phonology in the above example), and the time course of this processing (e.g. happens early before the word is even fixated by the skilled reader)[2].

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we are now discussing eye movement¦ licerotnre in reading
                               *
we are now discussing eye movement¦ literature in reading
                                       *
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Figure 1. the boundary paradigm where an invisible boundary is placed in the text (the dotted line) before the readers eye cross it (the first line) an orthographically similar non-word (licerotnre) is given as a parafoveal preview of the target word (literature). The asterisks indicate the locations of eye fixations.

[2] It is worth noting that the extent and limitations of parafoveal processing remain active areas of investigation and academic discussion which are beyond the scope of this work. The interested reader is referred to other reviews (e.g. Drieghe, 2011; Hyönä, 2011) for further information.

Tracking eye movements[3] during reading has become one of the main ways of investigating the cognitive processes readers perform while they read text in real-time. This is mainly because: (a) eye movements are regarded as accurate indicators of cognitive functioning during reading, a point which will be unpacked in the following paragraphs; and (b) because tracking eye movements, particularly using modern equipment which are both subtle and powerful, is regarded as the most natural, non-invasive means of investigating readers' cognitive processes.

Reliable evidence clearly show that, during reading, eye movements are "inextricably bound" to readers' cognitive processes (Rayner & Liversedge, 2011 p.757). And because no other tasks are being performed (e.g. word naming or LDTs) to disrupt the progress of natural reading, a record of a reader's eye movements can provide an accurate account of their *online* cognitive processes and the time progression of these processes. This is the core of what is termed the *linguistic/cognitive position* of eye movement research (Rayner & Liversedge, 2004; 2011; also Liversedge & Findlay, 2000).[4] Experimental tasks using *offline* methodology (word naming, LDTs, word-categorisation), as discussed above, are typically concerned with single-word processing, rather than with studying the complex processes of natural reading (Juhasz & Pollatsek, 2011), and they have clear shortcomings and limitations (Rayner & Liversedge, 2011). Not least amongst these shortcomings is ignoring the effects of sentence context on word recognition (e.g. Juhasz, Pollatsek, Hyönä, Drieghe, & Rayner, 2009). Simply put, if the purpose of reading is to comprehend text, then during reading all cognitive processes, including those which control when and where to move the eyes, are directly involved in facilitating text-to-meaning conversion. The question is how do we know that eye movements are thus *inextricably linked* to the readers' cognitive processes? The answer proposed here will illustrate that eye movement records show clear, consistent and measurable effects of the two main components of the reading process: a) the linguistic properties of the text being read, and b) the 'properties' of the reader

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[3] It is appropriate at this stage to advise the reader that throughout this discussion, whenever the term *eye movements* is used, it will be referring to the whole repertoire of eye behaviours, whether movements (saccades) forwards or backward regressions, or fixations. Of course at numerous locations the discussion will be clearly specific to one or other of these eye behaviours.

[4] Interested readers can compare this view to the "oculomotor" view (e.g. Vitu, 2011); such comparison although interesting, would be outside the remit of this work.

him/herself in terms of level of skill, previous world knowledge, age etc. And it is to such evidence that this discussion now turns.

Researchers using eye movements to study the cognitive processes associated with natural reading typically present their participants with sentences which contain certain linguistic manipulations (e.g. inclusion of certain words of varying length, frequency of occurrence in the language, number of meanings; sentential clause complexity; presence or absence of misleading information, or so-called garden-pathing where, upon encountering a disambiguating word or phrase, readers' discover that their interpretation of a sentence was inaccurate and thus the ensuing cognitive processes aim at recovering from being led up the garden-path, etc.). The researchers are typically interested in how the readers' eyes behave in certain predefined regions of these sentences (Clifton, Staub, & Rayner, 2007). These regions can be one or several words long, and the researchers look at some specific eye movement measures (see Table 1) when analysing readers' performance at these regions.

1.4.1 Word Frequency Effects on Eye Movements

Starting at word level, research has shown that the properties of the fixated word influence the length of time the eyes spend on that word. For instance, seminal investigations have recorded that word frequency impacts upon fixation duration such that, for words of equal length, less frequent words attract longer fixations compared to words which occur more frequently in the language (Inhoff & Rayner, 1986; Rayner & Duffy, 1986; see also Juhasz & Rayner, 2003; 2006; Pollatsek, Juhasz, Reichle, Machacek, & Rayner, 2008; Reingold, Yang, & Rayner, 2010; Staub, White, Drieghe, Hollway, & Rayner, 2010). Other evidence shows that high frequency words may be skipped altogether, that is, the eyes are directed not to fixate them, rather, to move to subsequent parts of the text, while less frequent words are much less likely to be skipped (e.g., Brysbaert, Drieghe, & Vitu, 2005; Brysbaert & Vitu, 1998; Rayner, Sereno, & Raney, 1996).

Attempting to further clarify the effects of word frequency on the cognitive processes, White (2008) noted that most investigations did not sufficiently control for *type frequency* (the number of words in a language containing a particular letter sequence, e.g. *-igh*) and/or *orthographic familiarity* (the sum of frequencies of words containing a certain letter string, see White, p.206) when investigating word frequency effects. The importance of this, according to White, is that orthographic familiarity and/or type frequency may have been responsible, wholly or partially, for the observed word frequency effects because more frequent words are by definition more orthographically familiar, and, also because the frequency of some letter strings

Table 1

Some of the Eye Movement Measures Reported in Reading Investigations

Measure	Definition and Time Course
First fixation duration	An early measure recorded at the reader's first pass at the sentence. Measures the time duration of the first fixation on a target word, irrespective of the total number of fixations this word receives.
Single fixation duration	An early measure recorded at the reader's first pass at the sentence. Measures the duration of the first fixation on a word which receives only one fixation during the first pass.
Gaze duration or first pass reading time	An early measure recorded at the reader's first pass at the sentence. Measures the sum of all first pass fixations on a target word.
Skipping rate	An early measure recorded at the reader's first pass at the sentence. Measures the percentage of instances where a target word is not fixated (skipped) on first pass.
Regression rate	A late measure recorded in later stages of processing. Measures the percentage of regression into or out of a target region.
Second pass duration	A late measure recorded in later stages of processing. Measures the time duration spent re-reading a target word after first pass, including zero times when a region is not refixated.
Total fixation duration	A late measure recorded in later stages of processing. Measures the sum of the time spent reading a target word (i.e. gaze duration + second pass duration)

Note. Based on Clifton et al. (2007) and Juhasz and Pollatsek (2011). As Clifton et al. remarked, the terms "early" and "late" need to be approached with due caution and with reference to the particular models of text processing adopted by the various authors. But generally, "late" measures are unlikely to reflect first-stage processing and vice versa.

(e.g. the relatively frequent prefix *irr-*) may impact upon the processing of low-frequency words. Thus, investigations which have not controlled for such factors may be presenting potentially confounded results. To address this, White presented 30 undergraduates in a repeated measures design, with target words embedded in frame-sentences (identical sentences which only differed between conditions in the target word they contained). The target words made up three conditions: (a) high-frequency and orthographically familiar, (b) low-frequency and orthographically familiar, and (c) low-frequency and orthographically unfamiliar. The results were unequivocal: word frequency impacted upon fixation duration and the probability of skipping words such that high-frequency words had shorter fixation durations (mean gaze duration 265ms) than low-frequency words (mean gaze duration 309ms) and were more likely to be skipped than low-frequency words. Furthermore, orthographic familiarity had a small impact upon fixation durations, but no influence on the probability of word skipping. White concluded that “lexical processing of fixated words can influence saccade programming, as shown by fixation durations, and that lexical processing of parafoveal words can influence saccade programming, as shown by word skipping” (p.215). Simply put, the lexical properties of the word being processed, namely, being of high frequency, allows cognitive processes of word identification to happen faster, thus the eyes need to fixate such word for shorter durations, and planning the next saccade can begin earlier. Similarly, a high frequency word may be sufficiently processed before it is even fixated (in the parafovea of vision), such that cognitive control decides that the eyes can skip the word altogether and direct the next fixation to subsequent text regions. Similar findings were reported by Drieghe, Rayner and Pollatsek (2008, who also replicated Brysbaert et al., 2005 in finding that high-frequency words were skipped more often compared to low frequency words). Furthermore, similar word frequency effects on readers’ eye movements were documented in other languages, for instance German (Kliegl, Grabner, Rolfs, & Engbert, 2004) and Chinese (Yan, Tian, Bai, & Rayner, 2006).

Perhaps most interestingly, independent teams of researchers have found that word frequency still exerts influence on eye movements, even if the target word is no longer visible. In what is known as the *disappearing text paradigm*, researchers show readers a target word in a sentence, which, once fixated by the readers, remains visible for the first 50-60ms of the fixation and then disappears. These researchers (Blythe, Liversedge, Joseph, White, & Rayner, 2009; Liversedge, Rayner, White, Vergilino-Perez, Findlay, & Kentridge, 2004; Rayner, Liversedge, & White, 2006;

Rayner, Liversedge, White, & Vergilino-Perez, 2003; Rayner, Yang, Castelhano, & Liversedge, 2011) found that how long the eyes remain in place is determined by the frequency of the word which has disappeared such that the fixation (on what has become a blank space) is longer if the word was of low frequency. While it can be argued that the disappearing text paradigm does not represent natural reading conditions, the replicated findings are compelling and allow us to confidently infer that "the cognitive processing associated with a fixated word are the engine driving the eyes through the text" (Rayner, 2009 p.1473; also Rayner & Liversedge, 2011). Equally interesting were the findings that encountering high or low frequency words repeatedly while reading a short text dampens the effects of word frequency on looking time: Rayner, Raney and Pollatsek (1995) reported that by the third encounter, no differences are found between looking times on low and high frequency words. This is a further demonstration that eye movement records are sensitive to online processes of increased familiarity resulting from the repetition of input. It also lends some support to theoretical claims in the *self-teaching* model (Share, 1995; 1999, see above) that increased automaticity is a characteristic of certain words, not readers.

1.4.2 Word Predictability Effects on Eye Movements

Another property of words which influences the readers' eye movements is word predictability. The word *coffee* is more predictable in the sequence:

(2) John is grumpy before he's had his morning coffee

whereas the word *shower* would be less predictable, although it still fits semantically. Early and current research documented that highly predictable words attract very short fixations, are more likely to be skipped, and less likely to attract another fixation compared to less predictable words (Balota, Pollatsek, & Rayner, 1985; Binder, Pollatsek, & Rayner, 1999; Drieghe, Brysbaert, Desmet, & Debaecke, 2004; Erlich & Rayner, 1981; Rayner, Binder, Ashby, & Pollatsek 2001; Rayner et al., 2011; Rayner & Well, 1996). This further highlights the close relationship between processing sentential meaning constraints and eye movements. The same findings are reported in other languages, German and Chinese for instance, where evidence shows that predictable words were more likely to be skipped than less predictable words (Kliegl et al., 2004; Rayner, Li, Juhasz, & Yan, 2005). The findings of these investigations are robust given the rigorous experimental control applied by the researchers. For instance, Balota et al. (1985) matched target words on length and frequency. Furthermore, they also obtained word predictability judgements (whether the target words, e.g. *coffee*, were really more predictable than replacements, e.g. *shower*) through a number of separately-conducted procedures with participants who did not take part in the eye tracking experiment. These procedures included presenting participants with the sentences with the target words absent and asking the participants to fill in the gap (cloze). Target words (e.g. *coffee*) were generated considerably more (about 64% of the time) than replacement words (e.g. *shower*, which was generated less than 1% of the time). Balota et al. also used a 5-point scale to get other participants to rate the predictability of target words (average rating for target words was 4.47 vs. 2.32 for replacement words).

1.4.3 Word Length Effects on Eye Movements

Similarly, word length (number of letters) was shown to have an impact on eye movements: longer words are less likely to be skipped than shorter (2-3 letter long) words (Brysbaert & Vitu, 1998; Kliegl et al., 2004, Rayner, 1979; Rayner & McConkie, 1976; Rayner, Slattery, Drieghe, & Liversedge, 2011; Vitu, O'Regan, Inhoff, & Topolski, 1995). Longer words also attract longer fixation durations compared to shorter words (e.g. Kliegl et al., 2004; Pollatsek et al., 2008; Rayner et al., 1996). Furthermore, Fitzsimmons and Drieghe (2011) demonstrated that the number of syllables also plays a role in directing eye movements to skip or to fixate target words. Fitzsimmons and Drieghe presented their participants with target 5-letter words which were matched on frequency (whole word and bigram), and number of orthographic neighbours. The main experimental manipulation was that these target words were either mono- or disyllabic (e.g. *grain* vs. *cargo*, respectively). Furthermore, and similar to Balota et al., (1985), they recruited another set of participants who took part in a cloze procedure to allow for a rigorous control over target word predictability, and who did not take part in the eye tracking experiment. Fitzsimmons and Drieghe observed that monosyllabic words were skipped on average 5.6% more than disyllabic words, which is considered a sizable effect which clearly shows that phonological processing may start in the parafoveal (see also Juhasz, White, Liversedge, & Rayner, 2008; White, Rayner, & Liversedge, 2005).

Additional evidence showed that the decision to move the eyes from the currently fixated word (word *n*) to the next word (word *n+1*), or to skip to the following word (landing on word *n+2*) seems to depend, amongst other factors (e.g. length of word *n+1*, see above), on the difficulties a reader may face in processing the currently fixated word, word *n*. Drieghe (2008), replicating the work of Reingold and Rayner (2006), came to this conclusion after documenting that his participants spent longer time (first fixation, single fixation and gaze durations, see Table 1) looking at target words (word *n* in the sequence *n* → *n+1* → *n+2*) when these words were made harder to process through decreasing display contrast (faint condition) or using cAsE aLtErNaTiOn manipulations. This led to a decrease in the probability of skipping word *n+1*, particularly in the faint condition. The difficulty in processing word *n*, due to the manipulations used, was thus shown to cause the cognitive system to become more "conservative" (p.860) in deciding whether or not to skip word *n+1*. These findings build on earlier findings which highlighted that the benefit of parafoveal preview of word *n+1* is reduced if word *n* is of low frequency (Henderson & Ferreira, 1990). Indeed, eye movement records show us that readers make as much progress into the text as the text difficulty allows them: while processing word *n*, readers' attention may shift to word *n+1* (the upcoming word) in the parafovea, and, if sufficient processing of word *n+1* happens parafoveally (while word *n* is still in the fovea), word *n+1* may be skipped and the eyes may be directed to saccade to word *n+2*. However, if word *n* is of low frequency, thus demanding more processing, parafoveal processing of word *n+1* is reduced, and the probability of skipping it is also decreased (Drieghe, 2008; Drieghe, Rayner, & Pollatsek, 2005).

1.4.4 Word Phonological Properties' Effects on Eye Movements

A word's phonological and prosodic properties also impact upon the readers' eye movements. For instance the number of stressed syllables influence the number of fixations made in high- and low-frequency words such that, in addition to the typical word frequency effects, words with two stressed syllables (high frequency: *radiation*, low frequency: *animation*) take longer time (gaze durations) to read and attract more fixations than words with a single stressed syllable (high frequency: *authority*, low frequency: *medicinal*, see Ashby & Clifton, 2005; Ashby, 2006; Ashby

& Rayner, 2004). These findings suggest that skilled readers typically access prosodic information during silent reading.

Other investigations showed that phonological access takes place early on in reading. First fixation durations were shown to be affected by the letter-sound regularity of the fixated word such that irregular words (e.g. *pint*) are fixated for longer than regular words (e.g. *dark*) and these effects were larger for low frequency words (Sereno & Rayner, 2000; also Inhoff & Topolski, 1994). Indeed, skilled readers are shown to be able to extract phonological information, including vowel information, from the upcoming (parafoveal) words, before even fixating them (Ashby et al., 2006; Chase, Rayner, & Well, 2005; Lee, Rayner, & Pollatsek, 1999; Miellet & Sparrow, 2004; Pollatsek, Lesch, Morris, & Rayner, 1992). Skilled readers in these investigations showed preview benefits for processing words of which the previews were phonologically similar (e.g. *peek* as a preview for *peak*) compared to orthographically similar previews (e.g. *peel*). Similar findings were reported in Chinese (Pollatsek, Tan, & Rayner, 2000). Furthermore, as discussed earlier, words with multiple phonological representations (e.g. *bows*), which also have multiple semantic representations, attract considerably longer fixation durations from the readers compared to words with single pronunciation and meaning (about 40ms, Folk & Morris, 1995) and to words which have multiple meanings but a single pronunciation (e.g. *bank*).

This brings the discussion neatly to recorded eye movement patterns when readers attempt to read words with multiple meanings (e.g. *bank*). Some of these words have more dominant meanings, that is, meanings which are used more frequently in the language (e.g. *port*, as a place for boats to dock being the dominant meaning, and as a type of wine being the less frequent one), while the meanings associated with other words are equally frequent (e.g. chest, part of human body, or a box, see e.g. Duffey et al., 1988). So, when reading sentences such as:

(3) Marcia quickly examined the table, and she couldn't see the cracks in it.

(4) Marcia quickly examined the table, and she couldn't see the caption for it.

the findings from eye movement investigations depict an intricate picture and further highlight how the cognitive processes of reading drive eye movement behaviours. Evidence indicate that for words with one dominant meaning (e.g. *table*, as a surface, with the less dominant meaning being a table containing data), and where the prior sentence context was neutral and the context after the target word supports the less frequent meaning of the ambiguous word (e.g. sentence 4), the readers made more regressions back to the ambiguous target word (Rayner, Cook, Juhasz, & Frazier, 2006). This pattern of eye movements indicates that the cognitive system, having through the force of habit adopted the more frequent meaning of the ambiguous word while reading the neutral context preceding it, was later in a state of disturbance when subsequent information indicated that the less frequent meaning was the correct one. This disturbance is captured in the eye movements' record, as the eyes were directed to regress to the ambiguous region to reappraise it.

1.4.5 Effects of Sentential Semantic and Syntactic Properties on Eye Movements

The findings of other investigations which aimed to explore the effects of sentence properties on eye movement behaviours can be summarised in the words of Clifton and Staub (2011): "Measuring where the eyes fixate, and for how long, has arguably been the most valuable way of exploring the time-course of comprehending written sentences" (p.895). Indeed evidence unequivocally show that the semantic and syntactic properties of the sentence being read impact directly upon the behaviour of the eyes, and thus allowing us to study the processes of reading comprehension. For instance, in a very influential paper, Frazier and Rayner (1982), put forward the *garden-path* model of sentence parsing, which utilised two simple principles: *minimal attachment*, or the idea that readers adopt the first and simplest interpretation of the sentence they can form based on the words they have already read; and *late closure*, whereby if this early simple interpretation is not available, then the readers adopt the interpretation which links new material (late in the sentence) to materials being currently processed. The following is a simplified account of the eye movement records of their participants. When reading misleading sentences where the internal representations which were created by the readers were violated, the readers seemed to execute a distinctive pattern of eye movement behaviours while they recovered from being misled. For instance reading:

(5) My little brother is cooking the chicken is burned to a crisp and so apparently we're not going to have anything to eat for dinner

readers typically construed that *the chicken* is the object of the verb "*cook*", not the subject of the passive segment "*is burned to a crisp*", and so they spent longer time fixating the region of the sentence which disambiguated the meaning (*is burned*). The readers' long fixations at the disambiguating region were accompanied by much shorter saccades (2-3 characters), compared to typical saccade size (7-8 characters) prior to entering the disambiguating region, and the readers also performed a larger number of regressions to the ambiguous region (*brother is cooking the chicken*). In effect, the readers were slowed down, having to spend longer times at the disambiguating region, which reflects their attempts at reappraising and reintegrating their thoughts with the actual presented text. The readers have also become less confident, moving their eyes shorter distances than is typically observed, and revisiting previously viewed portions of the sentence to recheck their (old and) new interpretations. These findings have been replicated in numerous subsequent investigations (e.g. Kemper, Crow, & Kemtes, 2004; Lipka, 2002; Liversedge, Paterson, & Clayes, 2002; Rayner, Carlson, & Frazier, 1983; Rayner & Frazier, 1987)[5].

Other evidence show that the readers' eye movements reflect the perturbation in the processing when they are presented with sentences which contain grammatical (syntactic) and semantic violations. Braze, Shankweiler, Ni, and Palumbo (2002) presented their participants with sentences like 6-8:

(6) The wall will surely ***crack after*** *a few years in this harsh climate. [Control, no violation]*

(7) The wall will surely ***bite after*** *a few years in this harsh climate. [Semantic (pragmatic) violation]*

(8) The wall will surely ***cracking after*** *a few years in this harsh climate. [Syntactic violation]*

They found that semantic violations (sentence 7) led to a marked increase in readers' looking times on the violating region (boldface), almost twice as long as the looking time recorded in control sentences. Syntactic violations (sentence 8) also led to an increase of looking time at the violating section, but were also marked by increased

[5] At least from the *garden-path* model's point of view, these findings do not mean that reading syntactically ambiguous sentences is slower than reading unambiguous ones *per se* (Clifton & Staub, 2011), because such a conclusion, although intuitive, would be an oversimplification which is not supported by evidence (e.g. Traxler, Pickering, & Clifton, 1998; van Gompel, Pickering, & Liversedge, 2005). Rather, eye movement records show that readers are slowed down only when they encounter portions of the text which contradict with, or violate, the interpretations which they have constructed up until that point.

regressions in the region containing the verb. These findings, namely that greater semantic violations lead to earlier and larger disturbances of processing, whereby the eyes fixate for longer or regress to particular text regions to allow the cognitive system to resolve these violations, are congruent with the other findings exploring different aspects of semantic and syntactic processing in English and other languages (e.g. Deutsch & Bentin, 2001, who studied processing of subject-predicate gender agreement/violation of animate and inanimate sentence subjects in Hebrew; also Ni, Fodor, Crain, & Shankweiler, 1998; Pearlmutter, Garnsey, & Bock, 1999; Rayner, Warren, Juhasz, & Liversedge, 2004; Warren & McConnell, 2007; Warren, McConnell, & Rayner, 2008). Taken together, this body of evidence highlights the sensitivity of eye movements as a measure of syntactic and semantic processing during reading.

Regressions are often made to correct a misplaced eye landing position, that is, if the eyes landed, erroneously, at a location which was not intended (see Clifton & Staub, 2011; Mitchell, Shen, Green, & Hodgson, 2008 for discussions). However, as discussed above, evidence indicates that regressive eye movements are made when readers' processing of the written materials is disrupted, for instance by encountering an unexpected word or portion of the sentence, the meaning of which violates the reader's current understanding. For instance, when reading:

(9) While the men hunted the moose that was sturdy and nimble hurried into the woods

readers' processing is disrupted at encountering "*hurried into the woods*", as, up to that point, the readers were thinking that the "*moose*" was the object of the verb "*hunted*". So, when presenting such sentences to readers, Mitchell et al. found that readers' eyes regressed from "*hurried*" to the ambiguous region "*hunted the moose*" which they had now to reappraise. According to Mitchell et al., these regressions may not be made as direct jumps to the ambiguous region (as in e.g. Frazier & Rayner, 1982, reading English; and more recently Meseguer, Carreiras, & Clifton, 2002, reading Spanish) and may be executed in steps. Mitchell et al. do not interpret their findings as contradicting the dominance of cognitive processes over eye movement control, or contradicting the corollary notion of *selective reanalysis* introduced by Frazier and Rayner (1982) whereby the eyes are *selectively* directed to regress and re-examine the region which is most relevant for ambiguity- or violation-resolution. Rather, Mitchell et al. interpret the step-like, indirect, regressions to such regions as an indicator of a sometimes inaccurate or "inefficient" ocular-motor control system (p.284).

Increased looking times and regression rates, and smaller forward saccade amplitudes are not the only eye movement behaviours which accompany experiencing problems in parsing sentences. Drieghe and his colleagues (Drieghe, Desmet, & Brysbaert, 2007) presented evidence that word skipping is also sensitive to whole sentence parsing processes. Improving the ecological validity of a previous work (Vonk, 1984) through asking participants to simply read for comprehension (rather than name aloud the referent of the sentence pronoun), Drieghe et al. showed that readers skipped Dutch pronouns when the previous sentential constraints rendered the pronouns redundant (e.g. when masculine nouns preceded the masculine pronoun *hij*, or *he*). However, the researchers noted that the masculine pronoun *hij* was skipped significantly more than the feminine pronoun *zij* (*she*). This was an unexpected finding. Drieghe and his colleagues put forward a *post hoc* explanation that since in Dutch the pronoun *zij* (she) can refer to both singular feminine (*she*), as well as plural (*they*), sentential constraining may have been rendered ineffective. Specifically, when the readers read "Laura apologised to Simon because *she*…" if *she* can also mean *they*, then the readers will not know if the sentence is about what Laura did, or about what Laura and Simon did, until later on. In such a situation the readers are not likely to skip the pronoun *zij* (she/they), and their eyes may spend longer fixating such sentences, resulting in longer total reading times. Both these effects were present in Drieghe et al.'s data. In addition to showing that word length is a key factor in word skipping, if Drieghe et al.'s post hoc explanation is true (and evidence indicate it is a very plausible explanation), then we have a clear situation where low-level textual properties (e.g. word length) as well as higher level properties (syntactic and semantic constraints) do influence the readers' eye movements such that a record of these movements is an accurate reflection of the interaction of textual properties and the cognitive processes associated with text-to-meaning conversion in natural reading.

1.4.6 Readers' Characteristics and Task Effects on Eye Movements

Another aspect of sentence processing which can be studied through examining readers' eye movement records is that of working memory load. In a recent investigation Gordon, Hendrick, Johnson, and Lee (2006) presented participants with sentences like:

(10) The poet that the painter inspired wrote an autobiography after their friendship became well known

This sentence is harder to process than when one of these is a proper noun, for instance:

(11) The poet that Philip inspired wrote an autobiography after their friendship became well known

In some of these sentences (e.g. sentence 10), the readers had to process two category-category subject and object words (e.g. *poet* and *painter*), whereas in other sentences (e.g. 11) they had to process category-noun subject and object words (e.g. *poet* and *Philip*). The similarity of category-category processing (vs. category-noun), and potential interference were hypothesised to have increased the working memory load in sentences like 10. Readers' eye movement records indeed show that they made more regressions in these sentences. Research in this area is however still in its infancy and it is expected that eye tracking will help in improving our understanding and refining of hypotheses relating to the impact of the memory load of text on readers' cognitive processes (Clifton & Staub, 2011).

Additionally, and to further illustrate the *tight coupling* between the on-going cognitive processes during reading and eye movement behaviour, evidence demonstrates that when participants are asked to perform tasks using text, other than reading it (e.g. searching), these participants' eye movement patterns no longer showed the typical observed and reported patterns associated with normal reading like frequency effects (Rayner & Fischer, 1996; Rayner & Raney, 1996). Similar findings are reported in the growing body of evidence which investigates *mindless reading*, or the common state where the readers' eyes keep moving in the text while their attention drifts away from text processing and comprehension. The eye movements of readers who self-reported episodes of mindless reading, or who were caught through comprehension questions, were qualitatively different from their eye movement records while reading (with attention): in mindless reading the typical language processing effects discussed above were simply absent (Rayner & Fischer, 1996; Reichle, Pollatsek, & Rayner, 2012; Reichle, Reineberg, & Schooler, 2010; Uzzaman & Joordens, 2011).

Other evidence which document the effects of more subtle and complex linguistic factors (e.g. sentence focus and finer-grain aspects of semantic and syntactic implausibility and anomaly) on eye movements are well documented, but detailing these would be beyond the scope of this elementary introduction. The interested reader is referred to Filik, Paterson, and Sauermann (2011); Filik, Paterson, and Liversedge (2005); Liversedge, Paterson, and Clayes (2002); Murray and Liversedge (1994); Paterson, Liversedge, Filik, Juhasz, White, and Rayner (2007); and Warren (2011) for original empirical work and comprehensive reviews.

Another important link in illustrating how eye movements can be considered as an accurate index of the cognitive processes in reading comes from the findings which show that eye movement records differ between readers, based on a number of reader-related factors. To start with, basic findings highlight age-related changes in readers' eye movements. Early investigations documented that eye movement records of older readers show slower saccades (Abel, Troost, & Dell'Osso, 1983) and overall slower reading times (Solan, Feldman, & Tujak, 1995). More recently, Kliegl et al. (2004) using a sample of 33 university students (mean age 21.9 years) and 32 older readers (mean age 69.9 years), documented that older readers read slightly more slower than younger readers (gaze duration 265ms for older adults vs. 230ms for the younger readers) and this difference reached statistical significance. Other researchers (Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006) found older readers' eye movement patterns suggestive of adopting riskier reading strategies which reflect the effects of both increased reading experience and age-related slowing of processing: Rayner et al.'s readers (average 77.5 years; range 70-92 years) showed larger frequency and predictability effects as well as a higher skipping rate compared to younger readers (average 23.9 years; range 18-34 years), however, the older readers made more regressions both to target words and to other areas of the text.

Eye movement research also showed that readers' experience with text is also manifest in what is known as the *perceptual span* (Rayner, 1975), which can be thought of as the area of vision where information can be accessed and processed to varying degrees. Typically, when reading left-to-right languages (e.g. English) readers make more use, parafoveally, of the letters shown to the right of fixation (i.e. the upcoming letters) than letters to the left of fixation (i.e. past letters). Investigations using an innovative technique called the *moving window* (McConkie & Rayner, 1975) have demonstrated that in left-to-right languages the readers' perceptual span can be up to 14-15 letters to the right of fixation, but only up to 3-4 letters to the left of fixation (Rayner, 1998). Using the moving window technique, researchers can control the amount of information (number of characters to the right and left of fixation) available to the readers, while masking or perturbing the presentation of other characters outside this ‘window’ to the left and right of fixation. The readers are free at all times to move their eyes, and with their eye movements, the window moves along. The assumption about using this technique is that when the window is as large as the region from which the reader can typically obtain information no differences in reading with or without window are observable. In languages which are read from right to left (e.g. Hebrew), the same perceptual span asymmetry is present, but in the opposite direction (Pollatsek, Bolozky, Well, & Rayner, 1981). Furthermore, in languages with dense presentation of written materials (i.e. when written characters present much visual information in a tight space, as in Chinese, Chen, Song, Lau, Wong, & Tang, 2003), readers have considerably smaller perceptual spans: about 1 character to the left of fixation and 2-3 to the right of fixation (Inhoff & Liu, 1997; 1998).

Other seminal findings (Rayner, 1986) showed that the level of difficulty of the text being read also affects the size of this perceptual span such that readers' span seems to be reduced when reading texts which are difficult for them—as if the cognitive system actively restricts the uptake of new information while it processes the current load. Typically, younger and less-skilled readers have a smaller perceptual span and their processing capacity is mostly spent on the fixated word, compared to older, more skilled, readers. For instance Häikiö, Bertram, Hyönä, and Niemi (2009; also Rayner, 1986; Rayner, Murphy, Henderson, & Pollatsek, 1989) showed that the perceptual span size increases until it reaches adult level by the age of 12, and that slower and less skilled readers have a smaller span compared to age-matched faster readers of all tested ages.

1.4.7 Findings of Eye Movements Research in Children’s Reading

There is a distinct paucity of eye movement studies with children. This paucity can be attributed mainly to methodological challenges, like selecting age-appropriate linguistic materials suitable for testing groups with different reading abilities (see Blythe & Joseph, 2011 for a detailed discussion). Dealing with this methodological issue, two groups of studies have reached similar conclusions. The first group comprises studies which have used different materials to suit the ability of the readers in each age group tested, thus all groups faced the same level of difficulty, at the cost of using different materials for each group (e.g. Blythe, Liversedge, Joseph, white, Findlay, & Rayner, 2006; McConkie, Zola, Grimes, Kerr, Bryant, & Wolff, 1991; Taylor, 1965). The second group comprises studies which have presented readers of all ages with the same sentences in order to avoid the differences in material becoming a confounding variable between groups, aiming their stimuli at the youngest readers tested, at the cost of presenting older readers with unusually easy texts (e.g. Blythe et al., 2009; Blythe, Häikiö, Bertram, Liversedge, Hyönä, 2011; Häikiö, Bertram, Hyönä, & Niemi, 2009; Huestegge, Radach, Corbic, & Huestegge, 2009; Joseph, Liversedge, Blythe, White, & Rayner, 2009; Joseph, Liversedge, Blythe, White, Gathercole, & Rayner, 2008; Rayner, 1986). Both these groups of studies found that age-related changes in eye movement records while reading are clear: older readers' sentence reading times and fixation durations are shorter, saccade amplitudes are larger, fixations and regressions are fewer, refixation probability is reduced, and word skipping probability is increased, compared to younger readers. In other words, older (skilled) readers' eye movement records clearly display their skill in picking up and processing textual information with less and shorter fixations, confidence to move the eyes over longer distances (saccade amplitude) into the text, less hesitation and need to revisit previous portions of the read text (less regressions and refixations), with adult-like eye movement behaviour patterns reached, broadly speaking, by the age of 11 (see Blythe and Joseph, 2011).

We discussed above evidence that adult readers' eye movements are affected by word length. Research with children has replicated these findings. Joseph et al. (2009), in an experiment where they controlled for word frequency and predictability to obtain pure word length effects, found that young readers' (7-11 years) and adults' eye movement records showed longer gaze durations, more fixations, and longer total reading times on long words (8 letters) compared to short words (4 letters). Furthermore, and in line with the claims made above about eye movements revealing developmental differences in reading ability, Joseph and her colleagues documented that the word-length effects described above were exaggerated in their younger readers, compared to adults: younger readers experience a higher processing load when dealing with long words such that lexical identification processes are made slower (see similar findings in Huestegge et al., 2009; and the less well controlled but rich dataset generated by Hyönä & Olson, 1995). Furthermore, when Blythe et al. (2011) limited these young readers' (8-9 years) initial fixation times to 60ms on the long words (through using the disappearing text manipulation, see above), these readers made up for this by making regressions (backward eye movements to refixate) to these words, leading to comparable fixation times to normal viewing conditions (with no disappearing text). Older children (10 years) and adults made considerably less regressions to the long words which have disappeared, indicating more efficient lexical identification system which is capable of identifying words after 60ms of viewing.

Furthermore, Chase et al. (2005) found that while their skilled readers were able to extract phonological information from the parafovea (the upcoming word), less skilled readers were not, and so they did not show the benefits from phonologically similar previews. Furthermore, where skilled readers' eye movements show strong word frequency effects, reflecting their efficient lexical access, less skilled readers eye movement records reflected stronger effect of word predictability, reflecting their less efficient lexical access and heavier reliance on sentence context to identify words (Ashby, Rayner, & Clifton, 2005). These findings further illustrate the value of using eye movements to study the impact of developmental changes (e.g. becoming more skilled at reading), while dealing with the processing demands of text reading.

Eye movement investigations also showed that the time course of detecting semantic implausibility differs depending on the skill level of the reader. Young (7-11 years) and adult readers were equally able to detect the implausibility in the sentence:

(12) The farmer used a duster to clean the dirty pigsty in his farm

with the difference being that children's eye movement records showed that this detection happens later in time, compared to adult readers (Joseph et al., 2008, using the experimental items of Rayner et al., 2004). This can be taken to further highlight the developmental differences between children and adult readers, which can be clearly captured in their eye movement records. The authors suggested that perhaps children's slowness to integrate world knowledge (e.g. about cleaning pigsties) into the reading comprehension processes, compared to adults is responsible for that delay (see also Trueswell, Sekerina, Hill, & Logrip, 1999). Joseph et al.'s work is the only one to date which attempted to explore children's eye movement patterns in relation to post lexical processes (the higher order on-line processes which take part after simple word identification) in normal text reading. Future replications of this work are required to further clarify the developmental course of semantic implausibility detection in skilled reading.

1.5 Summary and Concluding Remarks

Compared to single word reading tasks (e.g. LDTs, word naming or categorisation), tracking readers' eye movements during natural reading of text is a more ecologically valid way to investigate the complex and intricate cognitive processes of text reading. Eye tracking can reveal to the investigator the effects of word and text properties (e.g. word length, predictability and frequency, and sentential complexity or semantic or syntactic violations) and the time course of processing these properties (phonological, semantic and syntactic). Through eye tracking, an investigator can see where and when the reader hesitates and decides to spend more time looking at a word, or return to previous sections of the sentence, or when the reader is confident enough to skip a word, and whether (and when) she returns to this word to gleam more information, to name but a few examples of eye movement behaviours. The cognitive processes which direct the eyes to behave in these patterns can be inferred from well-controlled experiments and using well-designed stimuli.

As indicated above, given the space limitations and the targeted audience, the review of the literature presented above was, by necessity, elementary and actively avoided theoretical and methodological complications which are more relevant to readers with a pure academic interest. Interested readers are referred to other more comprehensive works (e.g. Liversedge, Gilchrist, & Everling, 2011; Rayner, 1998; 2009) which further explore these issues.

For the applied psychologists in the field of education, the literature reviewed above, particularly concerning the Self-teaching model (Share, 1995; 1999; Cunningham et al., 2002; Kyte & Johnson, 2006) and the literature reviewed about word frequency effects on readers' eye movement records, further supports the stance adopted by most educational psychologists that reading and literacy difficulties cannot be approached as within-child problems (Woolfson, 2011). Evidence clearly show that, as described above, automaticity in reading is a property of words, not of readers. If appropriate teaching strategies are deployed and sufficient practice is allowed, most pupils, including those with literacy needs, would be enabled to make progress (Kelly, 2008).

The literature reviewed also lends support to the professional drive for early identification of reading needs. Young pupils who seem to read (whole words) confidently at early stages of development, but without developing phonological decoding skills, and whose decoding needs are not identified until later, are likely to experience more difficulty and frustration as they develop as readers (Schatschneider, et al., 2004). Early identification, and, once again, using appropriate teaching methods which aim at improving accuracy and fluency (e.g. precision Teaching, e.g. Kubina & Morrison, 2000), as advocated by educational psychologists should allow such pupils to have a more positive experience when learning and developing their literacy skills. This is particularly important before reaching secondary education, given how complex dealing with such needs at this stage can become (see above, and Lingard, 1997; Shankweiler et al., 1996).

Furthermore, for the applied psychologists in the field of education, research using eye tracking methodology remains of low profile, although it utilises similar behavioural principles to those well-recognised and accepted in the field of educational psychology. Eye movements are behavioural responses which can be recorded with great precision in research activities to gauge, for instance, shifts in pupils' behavioural responses to remedial teaching. This is very similar to the almost universally accepted and widely used methods of precision teaching which, in teaching situations, aim to precisely record the shifts of pupils behavioural responses to teaching in terms of improvements of both fluency and accuracy (e.g. Binder, 1988; 1996; 2003; Chapman, Ewing, & Mozzoni, 2005; Hartnedy, Mozzoni, & Fahoum, 2005; Hughes, Beverley, & Whitehead, 2007; Kubina & Morrison, 2000; Kubina & Starlin, 2003; Kubina, Ward, & Mozzoni, 2000; Merbitz, Miller, & Hansen, 2003; White, 1986). From the same standpoint, and in the light of the literature reviewed above, tracking pupils' eye movements in research settings can be considered a finer method of evaluating pupils' improvements following remedial interventions, using the behavioural changes in their eye movements' as evidence for increased fluency and accuracy, for instance in dealing with certain words or with certain grammatical structures. Using eye movement research methodology more widely in educational research thus represents a natural development which is suitable for trainee and established educational psychologists with interest in psychological research to adopt. Working closely with established scientists to produce high quality evaluations of teaching interventions amounts to educational psychologists setting their own acceptable research and practice standards at a time when they merely get invited to, rather than instigate, national dialogues about the nature of their own practice and the quality of research evidence which should guide it.

As outlined above, an issue of particular interest which can be studied using eye tracking methodology is the role of phonological processing in facilitating semantic and syntactic processing. As argued above, while eye movement investigations can allow us to explore this question fully, it is not possible to carry out this exploration satisfactorily in languages with Roman alphabets. Rather, Semitic languages (e.g. Arabic) represent a better medium for such investigations given that the presence or absence of phonological information in these writing systems can be more tightly controlled. Eye movement investigations in this area will have wider implications reaching beyond the specific language being studied (e.g. Arabic or Hebrew) and can help us better understand the universals of the use of phonological information in processing text in natural skilled reading. This can potentially allow us to re-examine the current and prevailing models of literacy development, which, as discussed above, remain lacking of empirical support. From an applied standpoint, this research would also serve to address the gap in in the knowledge available to educators as to how readers use phonology in *online* natural reading, and how they repair their understanding and recover after making decoding errors, and how this can be linked to more effective teaching (and remedial teaching) strategies.

Chapter 2

The Contribution of Phonological Access towards Syntactic and Semantic Sentence Processing: Eye Movement Evidence from Arabic

2.1 Abstract

We aimed to explore, for the first time in a natural reading task, the interaction between phonological access and syntactic and semantic processing. We elected to carry out the investigation using Arabic given its phonological system which can be manipulated while retaining word orthography intact. We presented adult native Arabic readers with active sentences, and passive sentences where verb phonology indicated the voice of the verb, and other passive sentences where the verb phonology was absent, thus potentially garden-pathing the readers. We tracked the readers' eye movements so that we can make inferences about their online cognitive processes during reading. We predicted to find similar patterns of eye movements to those reported in previous investigations (e.g. Frazier & Rayner, 1982) when the readers were garden-pathed (interpreting a sentence as active, then discovering it was passive). Indeed, our analyses, of global (whole sentence) and local (certain sentence regions) measures of processing presented unequivocal patterns of the readers' eye movements. We replicated the findings of previous investigations with similar readers' eye movement patterns when they were garden-pathed: the readers spent longer reading times of the garden-path sentences, looked longer at the regions which helped them disambiguate the sentence, and displayed patterns of eye movements suggestive of selective reanalysis when reappraising key sentence regions. Importantly, we present, for the first time, findings which elucidate how skilled readers access phonology during natural reading; the time-course of this access, and its interaction with syntactic and semantic processing. Implications for educational, and educational psychology practice, are briefly discussed.

2.2 Introduction

To most educators and researchers phonology is mostly thought of in terms of its importance to reading development and literacy acquisition (see e.g. Lavidor, Johnston, & Snowling, 2006; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001; Snowling, Duff, Petrou, & Schiffeldrin, 2011). As discussed in the previous chapter, phonology features in developmental models of reading, and acquiring the alphabetic principle is considered a turning point for developing readers which marks their increased ability to segment and blend novel letter strings, pronounce these strings and learn them as new words (e.g. Ehri, 2005).

Similarly, to cognitive scientists, the interest in phonology has classically been directed to understanding single word processing, in terms of lexical access, memory load, priming effects, etc. (see e.g. Service, Ferrari, & Palladino, 2011; Trost & Gruber, 2012; Wilson, Tregellas, Slason, Pasko, & Rojas, 2011). The majority of these investigations have had little interest in how phonological access facilitates, and interacts with, other processes during natural reading, or have used off-line methodology (e.g. priming) to investigate the interaction between phonological and syntactic access in non-reading tasks (e.g. Santesteban, Pickering, & McLean, 2010). Another group of researchers whose main interest is in studying the cognitive processes which readers perform during natural reading are cognitive scientists and psycholinguists who use eye tracking methodology to study these processes. The merits of using eye tracking methodology were covered at length in the previous chapter. However, even this group of researchers has thus far been restricted in their studying of on-line phonological processing during natural reading with, foremostly, research questions that focused on phonological access of words in the text. The limitations of this research are mainly that its findings are seldom, if ever, integrated with other accounts about, for instance, sematic (meaning) or syntactic (grammar) processing to allow for an integrated understanding of natural reading to emerge. The second limitation which was discussed in the previous chapter relates to the research community depending solely on Roman alphabetic languages, particularly English, when studying language processes and natural reading. The scientific community is becoming increasingly aware that this approach cannot allow for universal accounts of human language processing to be developed (Frost, in press).

The type of integrative questions which motivated this research relates to how readers access and use phonology as they read texts of varying degrees of complexity. Do readers make use of phonological information to facilitate syntactic and/or semantic processing? What is the time course of these interactions, that is, when, in the reading process can a researcher observe these interactions and their effects? And, from an applied point of view, what are the educational implications for curriculum development and for teaching practice?

To begin answering some of these questions, we decided to use Arabic, a Semitic language whose phonological properties can allow us to construct well-controlled stimuli. Arabic is mainly a consonantal writing system which uses additional markers which are placed on top of, or below, letters to indicate how each letter should be vowelized (pronounced). These marks are known as diacritical marks (diacritics hereafter), and which readers are typically taught to decode in their early education (up to 9-10 years of age). These diacritics are then removed from mainstream texts (books, newspapers etc.) and appear only in religious texts or poetry (Abu-Rabia, 1998). Evidence shows however that readers of both Arabic and Hebrew of all ages and reading ability benefit from the presence of these diacritics (Abu-Rabia 1996; 1997a,b; 1998; 1999; Ravid & Shlesinger, 2001). Our decision to use Arabic stems from the fact that experimental manipulations to its phonology, as described in the previous chapter (also see below), are not confounded by orthographic changes (e.g. changes to letter order or identity). This allows us a greater experimental control. Furthermore, the fact that readers of Arabic are used to encountering both diacritised and non-diacritised texts serves to improve the ecological validity of our manipulations.

To test the interaction between phonology, syntactic and semantic processing we intend to use potentially grammatically misleading sentences in a classic garden-path experimental stimuli. In garden-path sentences, the readers typically develop their own interpretations of the materials being read until they encounter a portion of the text which conflicts with their interpretations and then realise they need to reappraise these interpretations, or that they have been led *up the garden-path*. We chose this paradigm given that it amplifies the interaction between syntax and semantics in a manner which allows researchers to investigate both (e.g. Frazier & Rayner, 1982; Lipka, 2002; Rayner, Carlson, & Frazier, 1983; Rayner & Frazier, 1987). For instance, the interpretation of the sentence:

(1) The horse raced past the barn fell

hinges on the reader accessing the appropriate grammatical representations of the verbs *raced* and *fell*. Classic investigations showed that readers are often garden-pathed by sentences such as this because the syntactic representation of *raced* leads them, erroneously, to think temporarily that the sentence is a simple active one, and later on they have to reappraise the meaning they derived from the sentence (e.g. Ferreira & Henderson, 1991; Frazier & Rayner, 1982; Kennedy & Murray, 1984). In this light, our task was to find means of adding phonological access as an additional factor which interacts with syntactic and semantic processes in the course of readers performing sentence comprehension. As we describe above (see also later), Arabic phonology system provided the best medium for conducting such an investigation.

As discussed in the previous chapter, tracking readers' eye movements has allowed psycholinguists to infer the cognitive processes which readers carry out during reading. Amongst these processes are the ones which readers perform to recover after discovering they have been 'led up the garden-path'. A seminal investigation of these processes by Frazier and Rayner (1982) proposed the garden-path model of sentence parsing and documented that readers made long fixations at the disambiguating region of the sentence, and these long fixations were accompanied by saccades of smaller amplitudes than normal prior to entering the disambiguating region. Furthermore, the readers also performed a large number of regressions to the ambiguous region, as they attempted to repair their interpretations of the sentences. These eye movement patterns are evidence that the readers were slowed down, and have become less confident and more conservative when progressing through the text.

Further research has documented similar findings (e.g. Meseguer, Carreiras, & Clifton, 2002). Readers of all ages seem to experience garden-path effects when reading misleading sentences, and, increasingly, we are learning about other implicated factors which impact upon the on-line cognitive processes of recovering from being garden-pathed. Some of these factors are related to the properties of the presented stimuli, for instance semantic plausibility (e.g. Pickering & Traxler, 1998; Rayner et al., 1983). Consider sentences (2) and (3), and the relationship between *the woman* and *the magazine* in both of them:

(2) As the woman edited the magazine amused all the reporters

(3) As the woman sailed the magazine amused all the reporters

(Examples from Pickering & Traxler, 1998)

In both these sentences, the readers assume a relationship between *the woman* and *the magazine* which is not supported by the sentence structure, that is, both sentences lead the readers up the garden-path. However sentence (3) adds semantic implausibility to the mix: *sailing a magazine* is an implausible act. Pickering and Traxler found that the readers misanalysed both types of garden-path sentences (plausible and implausible), and this was evident in their eye movement records (total reading times and rate of regression), with plausibility effects appearing before the garden-path effects.

Other factors which may interact with the garden-path effect may be thought of as related to the reader's own characteristics. For instance, Kemper, Crow and Kemtes (2004), examined the impact of working memory (WM) span on readers' ability to process, and recover from, misleading sentences. They found that the readers did indeed make more regressions to the critical sentence regions in ambiguous sentences and that their first-pass reading times were longer on the pre-specified regions as a function of sentence ambiguity. Furthermore, they showed that eye movement measures (first-pass reading duration, number of regressions to previous portions of text) were sensitive to participants' WM spans, with high-WM-span readers making shorter first-pass reading durations and less regressions to the critical sentence region when attempting to disambiguate the sentence meaning. The findings of this work are highly reliable as the researchers controlled for their participants' levels of education. The materials used at this experiment also maximised ecological validity through using well constructed, meaningful and syntactically accurate stimuli.

In this investigation we aim to begin to learn about the role phonological processing plays and how it interacts with syntactic and semantic processing in skilled readers during natural reading. This is a necessary first step before we can make meaningful comparisons with readers who have phonological processing difficulties. We will use a simple verb manipulation to create garden-path effects which utilises the fact that in written Arabic active verbs are more common than passive (e.g. دفع = *he pushed*). Indeed, preference is given in writing to the active voice (Schultz, 2004). The passive form of the verb is orthographically identical to the active (e.g. دفع = *he was pushed*). The only difference between the two verbs is the phonological information, which can be added as diacritics: دَفَعَ is active and is pronounced /d^{a}f^{a}a^{a}/,

دُفِعَ is passive and is pronounced $/d^{o}f^{i}a^{a}/$ (e.g. Haywood & Nahmad, 1965). Thus, we could construct sentences where the readers may be garden-pathed with regards to the voice of the verb and with regards to the agent and the patient of the sentence if the phonological information was absent (i.e. in sentences without diacritics). Similarly, if the readers do not make use of the available phonological information (in diacritised sentences), they will also be garden-pathed. Table 3 in the following section shows an example sentence which illustrates our manipulation.

In addition to using phonology to discover that the verb is passive, the readers may also make use of what we termed the *verb auxiliary*. Like in English sentences, the agent of passive sentences maybe mentioned towards the end of the sentence as in[6]:

(4) دفع اللاعب أحد لاعبـــي الفريق الأخر

[The footballer pushed another player from the other team]

The verb auxiliaries in Arabic can be used to add specific information about how the agent performed the act in the passive sentence, like the underlined part in:

(5) دفع اللاعب بيد أحد لاعبـــي الفريق الأخر

[The footballer was pushed by the hand of another player from the other team]

Another useful feature about writing in Arabic is that verb auxiliaries are, mostly, made up of one single word (e.g. بيد = *by the hand of*). This is ideal for preparing stimuli for our eye tracking experiment as it allows a degree of control over the size of the sentence region containing the verb auxiliary which is to be analysed. Furthermore, we can predict that in our stimuli, if the phonology (diacritics) which disambiguates the verb voice are absent, the readers would assume that they are reading active sentences (given the natural bias towards active voice interpretation in Arabic) until they arrive at the verb auxiliary. At this point, the readers should experience the garden-path effects.

We thus planned to present our participants with Arabic sentences in 5 conditions to examine whether they will show the classic garden-path effects and recovery strategies in their eye movement records (e.g. Frazier & Rayner, 1982). Table 1 lists these conditions.

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6 Note that reading direction is right-to left in Arabic.

Table 1

Breakdown and Details of Our Experimental Conditions

Sentence Condition	Description & Comment
Active non-diacritised	Baseline condition resembling the majority of currently published Arabic texts
Active fully-diacritised sentences	Resembling religious texts and poetry, and allows us to investigate the impact of the presence of full sentence diacritics on natural reading
Passive no-diacritics sentences	The critical condition where participants may get garden-pathed due to the lack of phonological information to mark the verb as passive
Passive fully-diacritised sentences	Resembling religious texts and poetry, and if the participants access the verb phonology they may be able to avoid the garden-path, and allows us to investigate the impact of the presence of full sentence diacritics on natural reading.
Passive basic-diacritics sentences, where only the verb is diacritised	Resembling natural modern Arabic texts where only potentially confusing words are diacritised**

Note. **We decided note participants with the basic-diacritics condition in active sentences because diacritics on the active verb will be an unnecessary and unnatural addition. Through discussions with Arabic book and newspaper publishers in Jordan, Lebanon, Egypt, Kuwait, and United Arab Emirates, we learned that diacritics appear in modern standard Arabic only on what would otherwise be misleading or confusing homographic words (words which look identical). Putting diacritics on the active verb in the basic-diacritics condition would therefore be an unnatural situation and negatively influence the ecological validity of our results.

With regards to the garden-path effects, in passive non-diacritised sentences we hypothesise to find similar effects to those recorded by Frazier and Rayner (1982), namely, increased reading times of these sentences. Also, as recorded by Frazier and Rayner, we expect that participants' eyes will regress to re-examine the verb region, particularly when it offers useful information, namely phonology (diacritics). Furthermore, the readers' eye movement records may show early effects (e.g. Kemper et al., 2004) due to the presence of verb-disambiguating diacritics in increased first fixation, single fixation and gaze durations, as well as a decreased skipping rate of the diacritised passive verbs. Furthermore, as the readers' eyes regress to re-examine the verb region, the additional processing time they spend at this region would be reflected in late measures (e.g. go-past times and total fixation durations, e.g. Frazier & Rayner, 1982). In short, and following Frazier and Rayner's findings, we expect that participants will spend longer reading times in the verb region, if this region allows the participants to disambiguate the sentence through the presence of phonology (diacritics). Otherwise, when no phonological information is present and the readers are garden-pathed, we anticipate them to spend longer times looking at the verb auxiliary region of the sentence. We also predict that the readers' eye movements will show different patterns in fully-diacritised compare to basic- or non-diacritised sentences but we are not certain about the direction of the effect.

The findings from our investigation will have a great impact upon our understanding of when and how readers access and process phonology during natural reading and how this access facilitates, or hinders, syntactic and semantic processing. The educational implications of our findings, particularly with regards to children who experience difficulties with phonological processing will be discussed.

2.3 Method

2.3.1 Design

A repeated measures design was used to investigate how the presence of phonology (diacritics) impacted upon readers' eye movement behaviours. The stimuli were counterbalanced and presented in random order such that all participants saw an equal number of target stimuli from the 5 experimental conditions (see Table 1), as well as from the foil sentences set.

2.3.2 Participants

Fifteen native Arabic speakers were recruited through study flyers (Appendix 1) and were paid £10 for participation. All participants lived in the southeast of the UK as residents or as visitors (e.g. international university students, or visiting siblings). The participants (11 females) ranged in age between 23 and 61 (mean = 37.1). All participants had normal or corrected-to-normal vision. The majority of participants spoke English as well as Arabic, importantly however, the possibility that the processes of reading Arabic in these participants would be contaminated by knowledge of English is limited given the extensive differences (e.g. in typology) between the two languages, unlike, for instance, speakers of Dutch and English (e.g. Brysbaert & Duyck, 2010). Table 2 provides additional information about the participants' Arabic reading experience.

2.3.3 Apparatus

An SR Research Eyelink 1000 tracker was used to record participants' eye movements while they read the on-screen stimuli sentences. Viewing was binocular, but eye movements were recorded from the right eye only. The eye tracker was interfaced with a Dell-Optiplex-GX745 computer, with all sentences presented on a 20 inch ViewSonic-G225f monitor that was set at a refresh rate of 120Hz. The participants leaned on a headrest, which supported their chin and forehead during reading to reduce head movements. Sentences were displayed on a single line and in natural cursive script using a non-monospaced font (Traditional Arabic, size 18, roughly equivalent to English text in Times New Roman font size 14) so that the reading experience is identical to natural reading (e.g. Almabruk, McGowan, White, Jordan, & Paterson, 2011)[7]. The other reason we chose this font is for the clarity with

[7] Although monospaced fonts are typically used in such experiments for technical reasons (i.e. ensuring words of equal word length take up equal space in the visual field) and for ease of analysis, our research and communication with other teams of researchers indicated that monospaced fonts, where

Table 2

Participants' frequency of reading Arabic, Exposure to Diacritised Texts and Time Living Away from Arabic-Speaking Country

ID	Frequency of Reading Arabic	% Of fully diacritised texts	% Of diacritised words in non-diacritised texts	# Of months in non-Arabic speaking country
1	Daily	5	0	40
2	Daily	30	20	36
3	Daily	10	5	45
4	Daily	1	1	38
5	Daily	2	2	39
6	Daily	0	3	8
7	About once a week, daily before this year	65 (With daughter)	4	14
8	Twice a week at least	30	50	50
9	Twice a week at least	30	60	36
10	Daily	5	1	0 visitor
11	About once a week	60	20	264
12	About once a week	20	60	264
13	About once a week	5	1	28
14	Daily	20	3	84
15	Twice a week at least	2	30	37
Means		19	17.33	65.53

all characters are of identical size, make Arabic script look unnatural to the native reader (e.g. A. A. A. Almabruk, personal communication, December 7, 2011).

which it displays the diacritical marks. The words were in black on a light grey background. The display was 70cm from the participants, and at this distance, 3.8 characters equaled 1° of visual angle.

Participants used a Microsoft gaming button box to enter their responses to the comprehension questions and to terminate trials after reading the sentences.

When participants read materials aloud (see below) their voices were recorded using a standard digital voice recorder.

2.3.4 Materials

Forty sentence-frames were constructed to contain the target verb in the 5 experimental conditions. Table 3 contains a sample sentence and shows that target verbs and the sentence patient were separated from the verb auxiliary in passive sentences (or from the object of the sentence in active sentences) with a long enough filler ("in front of many media photographers") to preclude parafoveal viewing of the verb auxiliary. As discussed in the previous chapter, readers begin processing upcoming words while these words are still in the parafoveal vision. Given that the verb auxiliaries used were made up of single short words, participants may have been able to process the verb auxiliary while still fixating the sentence's patient and thus discover early on that the sentence was of a passive voice. This would have considerably weakened the garden-path effect. Furthermore, and following Frazier and Rayner (1982), none of the sentences contained internal punctuation (e.g. commas) to rule out any potential role of punctuation in supporting sentence parsing, in addition to the fact that the inclusion of commas was entirely optional in our sentences. The sentences were counterbalanced such that each participant saw each sentence only once in one of the 5 conditions.

Sixty foil sentences of similar length and complexity, and which also contained active or passive verbs, with full, basic, or no-diacritics, were presented to all participants in addition to the 40 target sentences. Ten additional sentences made up the practice trials, thus each participant read 110 sentences in total.

Some sentences (25%) were followed by comprehension questions (e.g. Juhasz, Pollatsek, Hyönä, Drieghe, & Rayner, 2009). About 75% of these questions did not probe into the main manipulation (i.e. who carried out the verb) to minimise participants suspecting the focus of the research, and to minimise the use of strategies,

Table 3

Sentence Structure in the Active and Passive Conditions.

	← Direction of Decoding is Right-to-Left ←						
Active:		Filler III	Patient	Filler II	Agent	Verb	Filler I
		فهوى إلى الأرض.	احد المتظاهرين	أمام العديد من مصوري الإعلام	الشرطي	ضرب	في أثناء الاحتجاجات علي لقاء رؤساء الدول الصناعية
Passive:	Filler III	Agent	Verb Auxiliary	Filler II	Patient (Deputy Agent)	Verb	Filler I
	فَهَوَى إِلَى اَلأَرْضِ.	اَحَدِ اَلْمُتَظَاهِرِينِ	بِعْصَا	أَمَامَ اَلعَدِيدِ مَنْ مُصَورِي اَلإِعلاَمِ	الشُرطِيُّ	ضُرِبَ	فِي أَثْنَاءِ الاِحتِجَاجَاتِ عَلَي لِقَاءِ رُؤَسَاءِ اَلدُولِ اَلصِنَاعِيةِ
Gloss	During the protests on the meeting of the heads of the industrialised states the policeman (was) hit in front of many media photographers (with the stick of) one of the protesters so he fell to the ground.						

Note. The Passive Condition is fully diacritised for illustration, including the critical diacritisation if the verb. The gloss provides the additions for the passive condition (the auxiliary) between brackets.

which may reduce the naturalness of the reading situation (e.g. Rayner et al., 2004; Warren & McConnell, 2007). Participants responded accurately, on average 83.7% of the time (SD = 8.38, range = 70.37 – 83.70).

All sentences (targets and foils) were normed whereby 10-ratings of verb commonness and 10-ratings of sentence structure naturalness were obtained from additional participants on 5-point scales (1 = the verb is rare/the sentence structure is highly unnatural, 5 = the verb is very common/the sentence structure is perfectly natural). These additional participants did not take part in the eye tracking experiment and were recruited using Amazon Mechanical Turkers[8]. Given that our participants can only take part in either the norming or in the eye tracking part of the investigation, recruiting this non-local participant group for norming allowed us to use our small local population of native Arabic speakers for the eye tracking part of the investigation. To ascertain as to these participants proficiency in Arabic, they were required to use each verb in an original new sentence, and the input of users who did not submit grammatically accurate sentences, or which contained spelling errors were rejected (Bohannon, 2011). The obtained ratings showed that the naturalness of our sentences was high (average = 4.37, SD = 0.40, range = 3.2-5, mode = 4+) and so were the commonness ratings of the verbs we have chosen (average = 4.46, SD = 0.35, range = 3.3-5, mode = 4+). We decided to use this procedure in the absence of good-quality Arabic language corpus from which to obtain reliable word frequency ratings. To date only one corpus exists (Aralex, see Boudelaa & Marslen-Wilson, 2010), and it remains a work-in-progress, which is currently limited to a relatively small cohort of newspaper vocabulary. Obtaining commonness ratings as means of

[8] Through the famous commercial web page, another service is available where distant workers, called Turkers, and who are reside in many countries around the world, can sign up to perform Human Intelligence Tasks (HITs) like translation or transcription, or any other set of tasks set by individuals or businesses, and lately academic institutions for research into social and language phenomena. The Turkers learn about the task requirements, the amount of monetary compensation, and the amount of time allowed to finish the task and then they choose to fulfill the task (or not), knowing that they will be paid only if the work is completed to the required standard. The Turkers were paid £10 for participation and are, by default, assigned a unique identifying number and thus cannot participate more than once. To avoid non-native speakers of Arabic taking part in the norming process, all task instructions were presented in Arabic and I asked them to place each verb they rated into a new, original and grammatically correct sentence. Placing these comprehension and production demands allowed us to exercise as much control over the quality of the process as if conducted in our lab.

controlling for word frequency takes into consideration popular usage of these words and is considered to provide a good index of actual word frequency (e.g. Chafin, Morris, & Seely, 2001; Juhasz & Rayner, 2003; Williams & Morris, 2004; see also Juhasz & Pollatsek, 2011).

Furthermore, a passage extracted from an Arabic newspaper (146 words) was given to participants to read aloud before taking part in the eye tracking experiment so that their fluency and accuracy at reading were checked. Apart from 1 participant who asserted she was a native speaker of Arabic but was not allowed to take part in the eye tracking experiment because of her lack of fluency, our participants were highly accurate in their passage reading (mean text reading accuracy = 98.86%, SD = 0.96, range = 97.26-100%). Finally, participants were presented with a list of single words (target words were 36, diacritised, presented with another 24 undiacritised words) to read aloud. The diacritisation patterns on the target words were similar to those of the target verbs in the frame sentences. We presented our participants with these words to test their fluency in using diacritics in decoding, a measure which may have some impact on our results (mean single word reading accuracy = 92.78%, SD = 8.52, range = 72.22-100%[9]). Both the initial screening passage and the word list were presented to participants to read on white A4 sheets.

2.3.5 Procedure

Following obtaining approval of the University of Southampton Ethics Committee (Submission 721, 2 September 2011), participants were sent an electronic copy of the information sheet (Appendix 2) 3-4 days before participating. Upon arrival, participants were given a description of the apparatus and instructions for the experiment and were allowed to give their written consent (Appendix 3) to take part in the testing session which lasted 35-45 minutes.

The eye tracker was then calibrated at the beginning of the experiment and the calibration was validated. For calibration, participants looked at a fixation circle which appeared at random order at one location of 3 presented horizontally in the

[9] The score of 14 of the 15 participants was > 80%, however a single participant scored 72.22%. The data from this participant was included given that her reading accuracy in text was 100% and that her performance on the comprehension questions presented after the stimuli was 77.8%, in line with other participants.

middle of the screen. Then each participant read 10 practice sentences followed by the 100 experimental sentences in a different random order, with appropriate counterbalancing procedure to ensure that an equal number of sentences from each condition was read. The participants were told to read silently, and that they would periodically be required to answer questions about the sentences.

Each trial started with a fixation circle (1°×1° in size) at the location of the first character of the sentence as part of the calibration procedure (i.e. the tracker registers that the participant's eye are fixating this point), and so that participants do not have to saccade to start reading the ensuing stimulus (e.g. Yan, Tian, Bai, & Rayner, 2006). The sentence was shown after participants successfully fixated on the circle. After reading a sentence, the participants pressed a response button on a button box to start next trial (or to answer the ensuing comprehension question).

2.4 Results

For all the comparisons reported below, the means of eye movement measures obtained are compared by-participant variability (*F*1, *t*1) and by-item variability (*F*2, *t*2).

2.4.1 Global Analyses.

The means obtained for the following eye movement measures for whole sentence in all conditions are presented in Table 4.

2.4.1.1 Total reading times.

Comparing the total reading times of the two active conditions (fully-diacritised, A_fd, and non-diacritised, A_nd, sentences), it took the participants about 206ms extra to read the fully-diacritised sentences. This large difference, although indicative, was however non-significant in by-participant or by-item analyses (all *t*s < 1, paired-samples *t*-tests).

Table 4

Descriptive Statistics of Eye Movement Global Measures

	Active		Passive		
Measure	Full Diacritics Mean (SD)	No Diacritics Mean (SD)	Basic Diacritics Mean (SD)	Full Diacritics Mean (SD)	No Diacritics Mean (SD)
Total reading times (ms)	11605.15 (4626.18)	11398.93 (3978.71)	11745.06 (4005.60)	12564.83 (4276.32)	12644 (4605.51)
Total number of fixations	44.20 (16.67)	45.13 (15.61)	45.92 (17.36)	47.28 (16.13)	49.79 (19.22)
Average fixation duration (ms)	262.08 (32.74)	254.54 (32.55)	260.00 (33.32)	270.98 (28.37)	256.10 (31.48)
Saccade amplitude	1.80 (0.26)	1.85 (0.32)	1.83 (0.23)	1.79 (0.32)	1.84 (0.28)

The picture was different for passive sentences. Comparing the total reading times of the 3 conditions (full-diacritics, no-diacritics, and basic-diacritics, or P_fd, P_nd, P_bd, respectively), a repeated-measures analysis of variance (ANOVA) revealed that there was a marginally significant effect of diacritisation on total reading times $F1(2,28) = 2.78$, $MSe = 3715956.31$, $p = .079$, $\eta^2 = .17$. This effect was not found in the by-item analysis $F2(2,78) = 1.41$, $MSe = 9909233.69$, $p = .25$, $\eta^2 = .04$. Further exploring of the marginal effect in the by-participant analysis revealed that participants read sentences with basic-diacritics significantly faster than reading sentences with no-diacritics (almost 900ms faster, $t1(14) = 1.79$, $p = .048$, with a medium effect size $r = .43$, one-tailed as this was the predicted direction of the effect). This effect was not present in by-item analyses $t2(39) = 1.30$, $p = .10$, one-tailed). The comparison between fully-diacritised passive sentences and those with basic-diacritics was also marginally significant whereby participants read fully-diacritised sentences around 820ms slower, $t1(14) = 2.11$, $p = .053$; $t2(39) = 1.74$, $p = .09$, two-tailed as we had no prediction about the direction of the effect. The comparison between fully- and non-diacritised passive sentences was however not significant with non-diacritised sentences being read about 80ms slower (all *t*s < 1).

2.4.1.2 Total number of fixations.

There were no differences between the number of fixations readers made while reading fully- or non-diacritised active sentences, in by-participant or by-item analyses (all *t*s < 1).

The comparisons were also not significant between the three diacritisation conditions in passive sentences either $F1(2,28) = 2.15$, $MSe = 55.89$, $p = .14$, $\eta^2 = .13$; $F2(2,78) = 1.48$, $MSe = 149.04$, $p = .23$, $\eta^2 = .04$. We tested our hypothesis that the presence of diacritics only on the verb (basic-diacritics) in the passive condition will facilitate readers' performance, and this was supported: participants made significantly less fixations on passive sentences which contained basic (verb-only) diacritics compared to non-diacritised passive sentences $t1(14) = -1.89$, $p = .04$ (one-tailed), with a medium effect size $r = .45$, but slightly weaker in by-item analysis ($t2(39) = -1.46$, $p = .08$). This trend replicates the numerical pattern observed in the total reading times (i.e. P_bd < P_fd < P_nd measures).

2.4.1.3 Average fixation duration.

Participants' average fixation duration in active non-diacritised sentences was significantly shorter than in fully-diacritised active sentences (8ms) $F1(1,14) = 5.24$, $MSe = 426.61$, $p = .04$, $\eta^2 = .27$, but with a tiny effect size $\omega^2 = .01$. This effect was however absent from analysis by-item $F2(1,39) = 2.65$, $MSe = 1137.79$, $p = .11$, $\eta^2 = .06$.

There was also a significant effect of diacritisation on average fixation duration in passive sentences in the by-participant analysis $F1(2,28) = 5.35$, $MSe = 892.97$, $p = .01$, $\eta^2 = .28$, with a tiny effect size $\omega^2 = .04$, and in by-item analysis $F2(2,78) = 4.50$, $MSe = 2381.01$, $p = .01$, $\eta^2 = .10$, again with a tiny effect size $\omega^2 = .09$. Pairwise comparisons showed that the fully-diacritised passive sentences had longer average fixation durations compared to the non-diacritised sentences $t1(14) = 3.08$, $p = .008$, with a large effect size $r = .64$; and in by-item analysis $t2(39) = 2.87$, $p = .007$, with a medium effect size $r = .42$, and marginally longer than sentences with basic-diacritics $t1(14) = 1.92$, $p = .076$, with the effect being more amplified in by-item analysis $t2(39) = 2.02$, $p = .05$, with a medium effect size $r = .31$. However there was no significant difference between average fixation duration on the basic- versus non-diacritised passive sentences (all *t*s < 1).

2.4.1.4 Saccade amplitude.

There were no differences in average saccade amplitudes between the active sentences (fully and non-diacritised conditions), or between the passive sentences (fully-, non- or basic-diacritics sentences), all *F*s were < 1.

2.4.2 Local Analyses.

Here we report eye movement measures at two critical regions of our sentences: the region containing the target verb in all 5 conditions, and the region containing the verb auxiliary in the 3 passive conditions.

2.4.2.1 Verb region analyses.

The means obtained for the following eye movement measures in the verb region in all conditions are presented in Table 5.

2.4.2.1.1 First fixation.

There were no differences in first fixation duration on the verb between the 5 conditions in by-participant analysis $F1(4,56) = 1.15$, $MSe = 7092.34$, $p = .34$, $\eta^2 = .08$, nor in by-item analysis $F2(4,148) = 1.61$, $MSe = 20873.61$, $p = .17$, $\eta^2 = .04$. However an observed numerical trend was that diacritised passive verbs (basic-diacritics condition) attracted the longest first fixations compared to the other conditions and the comparison with non-diacritised passive verbs approached significance in by-participant analysis $t1(14) = 1.58$, $p = .069$ (one-tailed), and was significant in by-item analysis $t2(39) = 1.68$, $p = .05$, with a small effect size $r = .26$.

Table 5

Descriptive Statistics of Eye Movement Local Measures in the Verb Region

	Active		Passive		
Measure	Full Diacritics Mean (SD)	No Diacritics Mean (SD)	Basic Diacritics Mean (SD)	Full Diacritics Mean (SD)	No Diacritics Mean (SD)
First fixation (ms)	311.53 (66.84)	301.03 (78.51)	351.04 (124.28)	310.83 (88.77)	295.69 (29.78)
Single fixation (ms)	317.65 (70.61)	300.97 (73.98)	357.99 (121.27)	320.34 (99.93)	304.10 (29.43)
Skipping rate	0.19 (0.16)	0.18 (0.19)	0.09 (0.10)	0.14 (0.14)	0.19 (0.10)
Gaze duration (ms)	369.30 (93.71)	373.76 (91.96)	442.58 (129.83)	431.22 (150.20)	380.67 (77.45)
Go past (ms)	596.21 (281.88)	492.51 (229.30)	559.17 (243.11)	552.10 (202.33)	439.35 (115.99)
Total fixation durations (ms)	869.50 (338.13)	799.37 (272.34)	922.45 (484.67)	967.84 (393.43)	813.18 (348.13)
Regression in	0.42 (0.21)	0.48 (0.23)	0.42 (0.27)	0.49 (0.31)	0.40 (0.22)
Regression in count	0.69 (0.43)	0.67 (0.47)	0.66 (0.47)	0.80 (0.56)	0.65 (0.54)

2.4.2.1.2 Single fixation duration.

There was no significant differences between the 5 conditions on single fixation duration in by-participant analysis $F1(4,56) = 1.31$, $MSe = 7740.76$, $p = .28$, $\eta^2 = .09$, nor in by-item analysis ($F2 < 1$). However the same trend was observed that diacritised passive verbs (basic-diacritics condition) attracted the longest single fixations compared to the other conditions, with the difference between basic and non-diacritised sentences again approaching significance $t1(14) = 1.57$, $p = .069$; $t2(35) = 1.57$, $p = .063$ (both one-tailed).

Analyses of local early measures of eye movements thus far show a pattern whereby participants spend the longest time looking at verbs in passive basic-diacritics, followed by verbs in passive and active fully-diacritised sentences, and the shortest times are spent at verbs in passive and active non-diacritised sentences. This contrasts with the pattern recorded above in the global analyses and this contrast will be explained in the discussion.

2.4.2.1.3 Skipping rate.

No significant effects on skipping rate were recorded between any of the conditions in by-participant analysis $F1(4,56) = 1.66$, $MSe = 0.03$, $p = .17$, $\eta^2 = .11$ or in by-item analysis $F2(4,156) = 1.58$, $MSe = 0.07$, $p = .18$, $\eta^2 = .04$. Testing our hypothesis that passive diacritised verbs in the basic diacritisation condition are less likely to be skipped compared to no-diacritised verbs, a paired samples one-tailed *t*-tests $t1(14) = -3.35$, $p = .003$, with a large effect size $r = .67$; $t2(39) = -2.15$, $p = .019$, with a medium effect size $r = .33$ supported our hypothesis.

2.4.2.1.4 Gaze duration.

We found a marginally-significant difference between the 5 conditions on gaze duration in by-participant analysis $F1(4,56) = 2.06$, $MSe = 17966.29$, $p = .098$, $\eta^2 = .13$. However, by-item analysis did not show this effect $F2(4,148) = 1.71$, $MSe = 41160.93$, $p = .15$, $\eta^2 = .04$. In both these sets of analyses, diacritised passive verbs, particularly in the basic-diacritics condition, attracted the longest gaze durations (difference between P_bd and P_nd approached significance in one-tailed paired samples *t*-tests by-participant $t1(14) = 1.46$, $p = .08$, and was significant in by-item analysis $t2(37) = 1.74$, $p = .046$ one-tailed, with a small effect size $r = .27$). This fits with the trend found so far in local analyses of early processing eye movement measures whereby P_bd > P_fd > P_nd. Another observed trend was that active verbs in fully-diacritised sentences attracted the shortest gaze durations, even compared to the baseline condition.

2.4.2.1.5 Go-past times.

No significant effects were found between go-past times on the verb between the 5 conditions in by-participant analysis $F1(4,56) = 1.73$, $MSe = 57468.53$, $p = .16$, $\eta^2 = .11$ or by-item analysis $F2(4,148) = 1.06$, $MSe = 130691.01$, $p = .38$, $\eta^2 = .03$. We tested our hypothesis regarding participants' eye movements showing effects of the presence of diacritics on the verb in late measures and our hypothesis was supported: diacritised passive verbs (basic-diacritics condition) attracted the longest go-past times compared to non-diacritised passive verbs $t1(14) = 1.93$, $p = .037$, with medium effect size $r = .30$; $t2(37) = 1.93$, $p = .031$, with small effect size $r = .29$, both one-tailed. Similarly, verbs in passive fully-diacritised sentences had longer go-past times compared to passive non-diacritised verbs and this comparison was significant by-participant $t1(14) = 3.04$, $p = .009$, with a medium effect size $r = .44$, but not significant in by-item analysis $t2(37) = 1.61$, $p = .12$. Another trend was that active verbs in fully-diacritised sentences attracted the longest go-past times compared to all other conditions.

2.4.2.1.6 Total fixation durations.

Analyses revealed almost-significant difference between the 5 conditions in both by-participant analysis $F1(4,56) = 2.50$, $MSe = 76651.85$, $p = .053$, $\eta^2 = .15$ and in by-item analysis $F2(4,148) = 2.11$, $MSe = 260053.14$, $p = .08$, $\eta^2 = .05$. An observed trend was that, once again, diacritised passive verbs (basic-diacritics and full-diacritics conditions) attracted the longest total fixation durations, compared to non-diacritised passive verbs. Specifically, passive verbs in the basic-diacritics condition attracted longer total fixation durations than non-diacritised verbs $t1(14) = 1.93$, $p = .037$, with a medium effect $r = .46$; $t2(37) = 2.01$, $p = .026$, with a medium effect size $r = .31$, both one-tailed. Similarly, fully-diacritised passive verbs attracted longer total fixation durations compared to non-diacritised verbs in both by-participant $t1(14) = 3.04$, $p = .009$, with a large effect size $r = .63$, and by-item analysis $t2(37) = 2.38$, $p = .023$, with a medium effect size $r = .36$. Finally, the comparisons between verbs in fully-diacritised sentences and sentences with basic-diacritics were non-significant (all ts < 1).

2.4.2.1.7 Regression in.

There was no significant difference between the 5 conditions in the likelihood of the readers making a regression to the verb region, or in the actual regression count (all *F'*s < 1). However, an indicative trend was that while diacritised passive verbs in fully-diacritised passive sentences were most likely to receive a regression, and did receive the most regressions, diacritised verbs in the basic-diacritics condition received considerably less regressions, even less than the baseline condition.

Together with the findings discussed above in the total fixation durations, which include fixations on the verb made in revisits (i.e. after regressions) to the verb region, we may infer some support for our hypothesis that diacritised verbs would receive additional processing at later stages as well as at early stages of sentence processing as indicated above.

2.4.2.2 Verb-auxiliary region analyses.

The means obtained for the following eye movement measures in the region of the verb auxiliary in passive sentences are presented in Table 6.

Table 6

Descriptive Statistics of Eye Movement Local Measures in the Verb Auxiliary Region

Measure	Basic Diacritics Mean (SD)	Full Diacritics Mean (SD)	No Diacritics Mean (SD)
First fixation (ms)	299.78 (72.75)	308.72 (53.29)	302.43 (38.02)
Single fixation (ms)	283.81 (69.38)	313.58 (51.32)	307.33 (61.57)
Skipping rate	0.19 (0.16)	0.13 (0.12)	0.14 (0.11)
Gaze duration (ms)	364.30 (96.79)	379.50 (63.18)	387.20 (84.12)
Go past (ms)	422.04 (148.10)	461.50 (191.50)	447.58 (149.17)
Total fixation durations (ms)	581.86 (322.68)	714.89 (373.89)	723.40 (399.68)

2.4.2.2.1 First fixation.

There were no differences in first fixation duration on the verb auxiliaries between the 3 passive conditions in by-participant or by-item analysis (all *F*s < 1). However, an observed trend was that in basic-diacritics sentences (i.e. when only the verb was diacritised), the verb auxiliary attracted the shortest first fixation duration, with the longest first fixations being given to auxiliaries in fully-diacritised sentences.

2.4.2.2.2 Single fixation duration.

There was no significant difference between the 3 conditions on single fixation duration in by-participant analysis $F1(2,28) = 1.09$, $MSe = 3698.17$, $p = .35$, $\eta^2 = .07$, nor in by-item analysis $F2(2,72) = 1.34$, $MSe = 11666.19$, $p = .27$, $\eta^2 = .04$. However the same trend was observed that in sentences with basic-diacritics, the verb auxiliary attracted the shortest single fixation duration, with the longest single fixations being given to auxiliaries in fully-diacritised sentences.

2.4.2.2.3 Skipping rate.

No significant effects on skipping rate were recorded between any of the conditions in the by-participant analysis ($F1 < 1$) or in the by-item analysis $F2(2,78) = 1.42$, $MSe = 0.04$, $p = .25$, $\eta^2 = .04$. Another non-significant interesting trend was that in basic-diacritics sentences, the auxiliary was more likely to be skipped, whereas in sentences with full-diacritics the auxiliary was least likely to be skipped.

2.4.2.2.4 Gaze duration.

No significant effects were found between gaze durations on the verb auxiliaries between the 3 conditions in by-participant or by-item analysis (all *F*s < 1). Again, an observed non-significant trend was that in basic-diacritics sentences, the verb auxiliaries attracted the shortest gaze durations, whereas in sentences with no-diacritics, the verb auxiliary attracted the longest gaze durations.

2.4.2.2.5 Go-past times.

No significant effects were found between go-past times on the verb auxiliaries between the 3 conditions in by-participant or by-item analysis (all *F*s < 1). An observed non-significant trend was that in basic-diacritics sentences, the verb auxiliaries attracted the shortest go-past times, whereas in sentences with full-diacritics, the verb auxiliary attracted the longest go-past times.

2.4.2.2.6 Total fixation durations.

Analyses revealed non-significant differences between the 3 conditions in both by-participant analysis $F1(2,28) = 1.75$, $MSe = 92704.24$, $p = .19$, $\eta^2 = .11$ and in by-item analysis $F2(2,76) = 2.35$, $MSe = 235851.71$, $p = .10$, $\eta^2 = .06$. An observed trend was that, once again, in basic-diacritics sentences, the verb auxiliaries attracted the shortest total fixation durations, whereas in sentences with no-diacritics, the verb auxiliary attracted the longest total fixation durations.

2.5 Discussion

The significant comparisons and the other trends which emerged from our analyses were revealing with regards to how, and when, the participants made use of the available verb phonology (diacritics). We begin by discussing the results obtained in the active conditions, followed by the findings from comparing passive conditions for which we had specific predictions, namely the basic- versus no-diacritics conditions, finally we discuss the observed patterns at passive fully-diacritised sentences.

Starting with the active conditions, we obtained a consistent trend whereby participants took considerably longer to read fully-diacritised sentences, compared to sentences with no-diacritics in total reading times. This can be attributed to the abundant visual and phonological information provided by the diacritics which the readers had to process. This additional processing load was also evident in significant longer average fixation durations and smaller saccade amplitudes on fully-diacritised active and passive sentences compared to sentences with no-diacritics.

Exploring the garden-path effect in passive sentences, we made the prediction that the readers would be garden-pathed: the readers were expecting that the target verb in each sentence would be active, and that the noun following it denoted the agent of the sentence. However, upon encountering the verb auxiliary in passive non-diacritised sentences, the readers were surprised as the auxiliary indicated that the verb was actually of a passive voice. The participants' eye movement records confirm that this was the case. The trends observed in the global analyses showed that sentences in the critical condition (passive non-diacritised) received the longest total reading times, and the readers made the largest number of fixations on these sentences (number of fixations was significantly less when verb phonology was present in the basic-diacritics condition).

Furthermore, similar to Frazier and Rayner (1982), we anticipated that the readers would make more regressions from the verb auxiliary to earlier regions in these sentences, particularly to the verb region, and particularly when this region offers useful information (i.e. phonology). Comparing the sentences in our critical condition (non-diacritised passive) to passive sentences with basic-diacritics (verb only) supported our hypotheses. The participants gave the diacritised verbs in the basic-diacritics condition the longest first and single fixation durations, and gaze durations. Furthermore, participants were least likely to skip the verb in the basic-diacritics condition (less than half the skipping rate of non-diacritised verbs in the critical condition). It is possible to hypothesise that the participants were less likely to skip the verb as it, visually speaking, stood out for being diacritised, but then they fixated it for longer so that they can process and benefit from the available phonological information. This was a successful strategy because the participants spent less total reading times on sentences with basic-diacritics compared to sentences with no-diacritics.

Additionally, and as predicted, measures of later sentence processing also show that verbs in the basic-diacritisation condition received much longer go-past and total reading times than non-diacritised verbs (critical condition). Once again, this seems to be an effective use of reading time given that the additional time the readers spent processing the verb phonology in the basic-diacritics led to reduced total sentence reading times of sentences in this condition as reported above.

Similarly, trends emerging from analysing the eye movement measures at the verb auxiliary region compliment the findings reported so far. The readers were making less use of the auxiliary when the passive verbs were diacritised, particularly in the basic-diacritics condition. Specifically, the auxiliaries received the shortest first and single fixation durations, shortest gaze durations, and were most likely to be skipped when the preceding verb was diacritised in the basic diacritisation condition. The same was evident in the later measures of go-past and total fixation durations.

Furthermore, the trends present in the regression-in measure (returning to the verb) further clarify the time course of participants' processing of verb phonology (diacritics). Specifically, in basic-diacritics sentences, the participants seem to have benefited from spending longer first-pass times (first and single fixations and gaze duration) on the verb region so they needed to make fewer regressions to it later on. Coupled with the fact that total reading times of these sentences (passive basic-diacritics) were reduced, it is possible to suggest that the presence of eye-catching phonological markers on the passive verb contributed to resolving sentence ambiguity earlier than when the verb's phonological markers (diacritics) were absent.

This brings the discussion to participants' performance on fully-diacritised passive sentences, for which we had no clear prediction as to the direction of effects. It is plausible to suggest that the participants benefited from the presence of verb diacritics in this condition but to a lesser extent compared to the basic diacritisation condition. For instance, global reading times show that fully-diacritised passive sentences were read faster than the critical (passive no-diacritics) condition but slower than the basic diacritisation condition (i.e. global reading time was: passive-basic-diacritics < passive-full-diacritics < passive-no-diacritics). Furthermore, in local measures, the readers spent more time on the verb (early and late processes) in the fully-diacritised condition, but not nearly as much as they did in the basic diacritisation condition, with the least amount of time spent on the verb in the non-diacritised condition (i.e. time spent on the verb was: passive-basic-diacritics > passive-full-diacritics > passive-no-diacritics). Even more illuminating were the trends recorded in the verb auxiliary region. The participants spent more time looking at the verb auxiliary in fully-diacritised sentences in early and late processing (gaze duration, go-past, and total fixation durations: non-diacritised > fully-diacritised > basic-diacritics). Furthermore, the participants made the most regressions to the verb region in the fully-diacritised passive condition, presumably to resolve the verb ambiguity which they do not seem to have accomplished during first-pass (first and single fixations and gaze duration). Putting all these trends together, it is possible to hypothesise that when the verb phonology (diacritics) was not salient because all the other words in the sentence were diacritised, the readers needed to regress more times to the verb, spent longer time examining the verb auxiliary, and on the whole took longer to process the sentence compared to the basic diacritisation condition.

At this stage, it is worth reiterating that some of the reported trends did not make it to statistical significance. Nonetheless, these trends are interesting because they are consistent across all conditions with the interpretation presented above. Namely, participants made use of the available verb phonology and this impacted on their decisions of when to move their eyes away from the verb, and how much use to make of the verb auxiliary. The trends in our findings replicate those reported in the seminal work of Frazier and Rayner (1982, see also Meseguer, Carreiras, & Clifton, 2002). Namely, we replicated the effects of increased early looking times (first-pass) on the regions relevant to disambiguating the sentence, as well as late measures (total reading times) on these regions.

Furthermore, we can characterise the eye movement behaviour of our participants in two main patterns: (a) early and late processing measures (skipping rates and looking times) indicated that they targeted diacritised passive verbs for additional processing, and; (b) that their interest in the auxiliary was dependent on the presence of diacritics on the preceding verb. In that sense, the participants seem to have been *selective* in their sentence reanalysis. Whether our participants' directly targeted the verb/verb auxiliary in single saccades, or indirectly through multiple saccades, the combined emerging pattern of looking times and skipping rates in both these regions (verb and auxiliary) indicate clearly a pattern of *selective reanalyses* (see Mitchel, Shen, Green, & Hodgson, 2008), which was proposed by Frazier and Rayner (1982, see also Meseguer et al., 2002). Simply put, the readers' eye movements indicate that they do not randomly target portions of text, or go serially forwards or backwards (see discussion in Frazier & Rayner, 1982). Rather, the readers target the most informative portions of the text, in this case the diacritised verb region, and, if they obtain the information they need at the verb region, they do not return to it, they do not spend a lot of time fixating the verb auxiliary, and they are more likely to skip the auxiliary altogether.

The increased looking times (both global and local measures) on sentences which are fully-diacritised is an interesting finding. As mentioned earlier, this may be due to the added visual (noise) resulting from diacritising all words, may be the result of the added phonological information these diacritics represent, or indeed a combination of both. Whether full-diacritics add visual or phonological (or both) processing load is an empirical question which is very interesting, especially in the light of previous findings that adding phonology in the form of diacritics improves the reading performance of readers of different ages and reading ability in both Arabic and Hebrew (e.g. Abu-Rabia 1996; 1997a,b; 1998; 1999; Ravid & Shlesinger, 2001). One way we may investigate this is through comparing readers' perceptual spans (see Rayner, 1975, and the previous chapter), using the moving window technique (McConkie & Rayner, 1975), while they read diacritised and non-diacritised texts with varying degrees of complexity (i.e. the need for phonology as a variable in some conditions; the presence of accurate vs. erroneous diacritics in others). This will allow us to determine whether or not readers actually access the phonological information presented in (visually cluttered) fully-diacritised texts.

Furthermore, our findings highlight what can be characterised as an interesting interaction between low-level visual properties of text, namely the presence of verb diacritics in the basic-diacritisation condition, and the higher-order language processes which control eye movements. It is evident that our readers were visually attracted to the presence of verb diacritics when the verb was the only diacritised word in the sentence (e.g. reduced skipping rate). However, they seem to have also deployed higher-level processes when accessing the phonological information represented by the diacritics, followed by syntactic and semantic information which allowed them to move between the verb and the verb auxiliary in a meaningful and efficient way, as described above. This is precisely the sort of knowledge we sought to uncover when we planned this investigation: the time course of phonological access and its interaction with other cognitive processes during natural reading.

Despite the consistency of the numerical trends reported in our results across the various measures, and despite the numerical magnitude of these trends (some running into several-hundred ms), some of our findings did not reach statistical significance. This may be explained by the degree of variability between participants in the heterogeneous sample which we recruited (e.g. in age, reading rate etc. which can all impact upon eye movement measures, see previous chapter). This is a typical problem which faces research when the members of a special population (cultural minority in our case) are sampled and where the small size of the available population necessitates examining all collected data (Field, 2009; Howell, 2007). Future investigations, where time limitations are less stringent, should aim to recruit larger samples to avoid this problem[10]. However, the high quality of the used stimuli and our innovative norming procedure are evident in the consistency and size of the obtained numerical trends.

In terms of educational practice, of particular importance are the implications of our findings to populations of pupils whose phonological processing may be less than optimal. A recent brain imaging investigation found that atypical phonological processing in dyslexic children might have a negative impact upon syntactic and semantic processing in natural reading (Sabisch, Hahne, Glass, von Suchodoletz, & Friederici, 2006). Our findings lend weight to Sabisch et al.'s findings: skilled natural reading utilises phonological access, and as observed in the performance of our participants, this access interacts with other aspects of sentence processing including semantic and syntactic processing. Support for pupils who have less-than-optimal phonological skills must therefore include—in addition to the traditional remedial teaching interventions—on-going support with syntax (grammar) and semantic (comprehension) processing to ensure their successful inclusion and full ability to access the national curriculum.

From an applied educational psychology point of view, our findings are important. It is vital for educators, as well as other stakeholders in pupils' literacy development (including parents and curriculum planners), that phonology is not thought of only in developmental terms (i.e. stages of acquiring letter-sound relationships; segmentation, blending etc.). Rather, our findings illustrate that even adult skilled-readers do depend on phonology in a very active way to help them better access the grammar and meaning of the text being read. These processes interact while readers, of all ages, including school children and adolescents, attempt to access and understand the materials at hand. Clear evidence (e.g. Calhoon, 2005; Holsgrove & Garton, 2006) suggest that when combining effective teaching methodology (e.g. peer tutoring) with sufficient emphasis on phonological instruction, pupils begin to make tangible progress in reading comprehension, syntactic processing and other

[10] Our power calculations (G*Power 3.1.2, Faul, Erdfelder, Lang, & Buchner, 2007) indicated that to detect a medium effect size (r = .30) with power $1-\beta$ = .95, a sample of 20 participants would be required. At power $1-\beta$ = .80 (e.g. Howell, 2007), a sample of 14 participants would be required.

areas of literacy acquisition. Our findings serve to clarify the link between these processes, and how they mutually support each other in the course of natural reading.

Furthermore, given that our findings illustrate how adult skilled readers make use of phonological information when parsing (or revering from mis-parsing) of sentences, it is necessary that applied psychologists in the field of education emphasise the importance of supporting older pupils who experience difficulty in processing phonology (e.g. Holsgrove & Garton, 2006). This is in addition to the traditional emphasis on teaching phonology systematically to younger readers. Future investigations should aim to compare both younger and older readers' eye movement records when garden-pathed to further understand how readers improve in using phonology *online*. This research should also be complemented by other eye movement investigations which aim to evaluate the efficacy of the available remedial teaching strategies for pupils who have difficulty with phonological processing. The input of applied psychologists in terms of guiding such research agendas can be of great value.

In carrying out this investigation, in addition to answering the specific research questions, our aim was to set as high a standard for research activity carried out by (trainee) educational psychologist as was possible given the time and resource limitations. As discussed in the previous chapter, the current author firmly believes in the importance of educational psychologists taking the lead in conducting such empirical investigations which utilises rigorous methodology (quantitative or qualitative), to generate evidence to inform their advice and practice. This is the only means of securing the professional independence of educational psychologists in terms of ownership of both: the standards of quality of practice in our own profession; and of the very definition of their role.

To conclude, in our investigation, we have used the phonological characteristics of Arabic to uncover some key aspects about the time course of phonological processing and how this interacts with syntactic and semantic processing in natural reading. These findings are of relevance to understanding language processing in universal terms. The implications of our findings are particularly important to educators when considering the role of phonology in both the acquisition of reading, and for the role phonology plays during skilled reading in facilitating better text comprehension.

Appendix 1

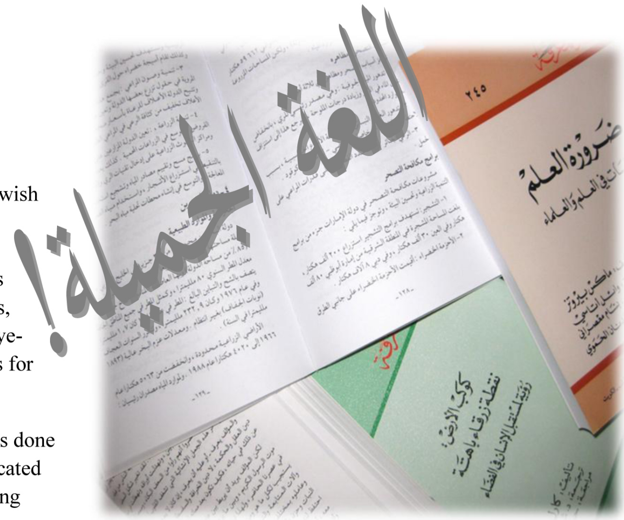
Study Flyer

Flyer Version 1.1_17/8/2011
Ethics Ref. 816 (Oct. 2011)

UNIVERSITY OF Southampton
School of Psychology

قراءة العربية: دراسة حركات عينين القراء عند قراءة مختلف أنواع الجمل العربية

Reading Arabic: An Eye Movements Investigation of Reading Different Types of Arabic Sentences



We are a team of researchers at the University of Southampton who wish to investigate how readers deal with different types of Arabic sentences, and we are using eye-tracking techniques for this purpose.

Tracking the eyes is done by using a sophisticated camera while reading sentences which are presented on a computer screen. Eye-tracking has been used to study reading processes of many languages, but as yet reading Arabic has not received the due attention.

Are you a native Arabic speaker? Are you 18 years or older? Do you enjoy normal vision (or corrected to normal by glasses for instance)? If your answer is yes, then you can help us study reading Arabic as it was never studied before! You will receive £10 as a small *thank you* for your participation, which should last about an hour. For more details, please contact Ehab on the email address:

نحن فريق من الباحثين بجامعة ساوثهامبتون و نريد أن ندرس كيف يتعامل القراء العرب مع مختلف أنوع الجمل العربية و نحن نستخدم طريقة مراقبة حركات العينين أثناء القراءة لهذا الغرض.

مراقبة حركات العينين تتم باستخدام كاميرا متطورة أثناء قراءة الجمل المعروضة على شاشة الكمبيوتر. لقد استخدمت طرق مراقبة حركات العينين لدراسة القراءة في العديد من اللغات لكن حتى الآن لم تُعطي قراءة اللغة العربية الاهتمام المستحق.

هل العربية هي لغتك الأولى؟ هل أنت تبلغ 18 عاما أو أكثر؟ هل تتمتع\تتمتعي بصحة النظر (أو ترتدي نظاره مثلا لتصحيح النظر)؟ لو كانت أجابتك نعم, إذا يمكنك مساعدتنا في دراسة قراءة العربية كما لم تدرس من قبل! سوف تحصل علي مبلغ رمزي (£10) تعبيرا عن شكرنا لمشاركتك و التي ستستغرق ساعة واحدة (تقريبا). للمزيد من التفاصيل تحدث مع إيهاب عنوان البريد الالكتروني:

ewh1g09@soton.ac.uk
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Appendix 2

Participants Information Sheet

UNIVERSITY OF Southampton
School of Psychology

Participant Information Sheet
(v.1.4/17_October_2011)

Study Topic
Reading Arabic: An eye movements investigation of different types of sentences
قراءة العربية: دراسة حركات عينين القراء عند قراءة مختلف أنواع الجمل العربية

Researcher: Ehab W Hermena
Ethics number: 816

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.
برجاء قراءة هذه الوثيقة بعناية قبل الموافقة على المشاركة في هذه الدراسة. سأقدم لك استمارة موافقة علي المشاركة للتوقيع لو رغبت المشاركة.

Who are the researchers and what is this research about?
We are a team of researchers at the University of Southampton who wish to investigate how readers deal with different types of Arabic sentences, and we are using eye-tracking techniques for this purpose. Tracking the eyes can lead to inferences to be made about the cognitive process the readers use to deal with the sentences. Eye-tracking has been used to study reading processes of many languages, but as yet reading Arabic has not received the due attention.

ماذا عن الباحثون و ما هو موضوع هذه الدراسة؟
نحن فريق من الباحثين بجامعة ساوثهامبتون و نريد أن ندرس كيف يتعامل القراء العرب مع مختلف أنوع الجمل العربية أثناء القراءة و نحن نستخدم طريقة مراقبة حركات العينين أثناء القراءة لهذا الغرض. مراقبة حركات العينين أثناء القراءة قد يسمح باستنباط العمليات الذهنية التي يقوم بها القراء أثناء القراءة. لقد استخدمت طرق مراقبة حركات العينين أثناء القراءة لدراسة القراءة في العديد من اللغات لكن حتى الآن لم تعطى قراءة العربية الاهتمام الكافي.

Why have I been chosen to participate?
As an adult, native speaking Arabic, you can help us learn more about reading Arabic.

لماذا تم اختياري للمشاركة في هذه الدراسة؟
لأن لغتك الأولى هي العربية, لهذا يمكنك أن تساعدنا لنفهم المزيد عن قراءة العربية.

What am I expected to do if I participate?
I will ask you to sign a consent form, and then the study will begin. I will ask you to place your head on the chin/headrest while I calibrate the eye-tracking the system so that it collects accurate information about what you are looking at. You will be sat at a computer screen and you will see some words which you will need to read aloud and accurately. After this, sentences will appear on the screen which you will need to read silently. Please read all sentences carefully and quickly. You have to read the sentences carefully because there will be questions following some sentences and you will press one button if the answer is 'yes', and a different button if the answer is 'no'. I will record your voice while reading the single words only. You will need to sit comfortably and not move so that the eye-tracking equipment can continue to collect

Appendix 2 Cont.

accurate data, this is an important matter. You can take a break if you feel you need to. Your participation should last for about 1 hour. You will receive £10 as a small thank you for your participation. This is the first study in a research programme and other new studies will be carried out in the future. We will ask you if you wish to leave with us any contact details so that we can invite you to take part in these future studies. Of course you do not have to leave us your details if you do not want to.

ماذا ينتظر مني أن أفعل إذا قررت أن أشترك في الدراسة؟
سأطلب منك توقيع استمارة الموافقة على المشاركة, وبعد ذلك تبدأ الدراسة. سأطلب منك أن تضع راسك علي مسند الرأس و الذقن بينما أقوم أنا بإعداد جهاز مراقبة العينين للتأكد من صحة المعلومات التي يحصلها الجهاز عن موقع عينيك أثناء القراءة. سيكون هناك شاشة كمبيوتر أمامك و ستعرض عليها كلمات والمطلوب منك بدقة و بصوت عال. بعد ذلك ستظهر جمل علي الشاشة و المطلوب منك قراءتها في صمت. برجاء قراءة قراءتها كل الجمل بدقة و بسرعة. عليك قراءة الجمل بدقة لان هناك أسئلة تتبع بعض هذه الجمل و سيكون عليك أن تضغط مفتاحاً علي لوحة المفاتيح لو كانت الإجابة نعم, و مفتاحا آخر لو كانت الإجابة لا. سوف أقوم بتسجيل قراءتك للكلمات المفردة (فقط) تسجيلا صوتيا. حاول أن تجلس مستريحا بدون حركة حتى يمكن لجهاز مراقبة العينين من أن يحصل معلومات دقيقة, هذه مسألة هامة. يمكن أن تطلب بعض الراحة لو شعرت انك بحاجة إلي ذلك. ستستغرق مشاركتك مدة ساعة تقريباً. سوف تحصل علي مبلغ رمزي (£10) تعبيرا عن شكرنا لمشاركتك. هذه الدراسة هي الأولي في برنامجنا البحثي و الذي سيتضمن دراسات أخري في المستقبل. سوف نسألك لو كنت ترغب في أن تعطينا أي معلومات عن كيفية الاتصال بك لندعوك للمشاركة في هذه الدراسات. بالطبع لا شيء يحتم عليك أن تعطينا هذه المعلومات لو لم ترغب في ذلك.

Are there any risks involved?
No additional risks to sitting in front of any computer screen, at home for example. The eye-tracking equipment is safe to use for the researchers and the participants.

هل هناك أية مخاطر إذا قررت أن أشترك؟
لا توجد أي مخاطر إضافية للجلوس أمام شاشة أي كمبيوتر, في المنزل على سبيل المثال. أيضا استخدام جهاز مراقبة العينين يخلو من أي مخاطر للباحثين و للمشاركين في الدراسة سواء.

What about my well-being while participating?
We hope you will enjoy taking part in this research. If you feel any discomfort or have any questions at any time during participation, please talk to me and I will do my best to help you. Before we start I will explain to you all the safety procedures relating to the lab and the equipment as well as other emergency procedures.

ماذا عن سلامتي أثناء المشاركة في هذه الدراسة؟
نحن نأمل أنك سوف تستمتع بالمشاركة في هذه الدراسة. لو شعرت بأي عدم ارتياح أو لو كان لديك أي سؤال أثناء المشاركة, أرجو أن تخبرني و سوف أحاول قدر استطاعتي أن أساعدك. قبل أن نبدأ سوف أقوم بشرح قواعد السلامة الخاصة بالمعمل و الخاصة بالأجهزة و أيضا قواعد السلامة في حالة أي طارئ.

Will my participation be confidential?
Yes. Any data collected will not be linked to your name. Your data and that of other participants will be stored and used on safe systems for handling information.

هل ستكون المعلومات الخاصة بمشاركتي محفوظة بشكل آمن؟
بالطبع. أية معلومات محصلة لن تنسب إلي أسمك. كل المعلومات المحصلة و الخاصة بكل المشاركين سوف تخزن و تستعمل علي أنظمة آمنة لتداول المعلومات.

Appendix 2 Cont.

What happens if I change my mind?
You have the right to terminate your participation in the research, at any time, without having to give any reasons, and without your rights being affected.

ماذا لو غيرت رأيي؟
لك الحق أن تنهي مشاركتك في هذه الدراسة، في أي وقت. و بدون إبداء أي أسباب، و بدون أي تأثير على حقوقك.

What happens if something goes wrong?
In the unlikely case of concern or complaint, please contact:
Chair of the ethics committee
Department of Psychology
University of Southampton
Southampton, SO17 1BJ.
Telephone: (023) 8059 5578.

ماذا لو حدث أي شي سلبي؟
في حالة أن يكون لديك أي شكوى، برجاء مراسلة:

Chair of the ethics committee
Department of Psychology
University of Southampton
Southampton, SO17 1BJ.
Telephone: (023) 8059 5578.

Where can I get more information?
Please don't hesitate to get in touch with me if you have any further queries. Please use my university email address: ewh1g09@soton.ac.uk

أين يمكنني أن احصل علي المزيد من المعلومات؟
برجاء الاتصال بي علي هذا العنوان للبريد الالكتروني الخاص بالجامعة:
ewh1g09@soton.ac.uk

Appendix 3

Participants' Consent Form

UNIVERSITY OF Southampton School of Psychology

Participants' Consent Form

(v.1.3/17_October_2011)

Study Topic

Reading Arabic: An eye movements investigation of reading different types of sentences

قراءة العربية: دراسة حركات عينين القراء عند قراءة مختلف أنواع الجمل العربية

Researcher: Ehab W Hermena

Ethics number: 816

Please tick the boxes if you agree with these sentences:

- I have been given enough information about the study and I understand what it is about ☐

قد حصلت على معلومات كافية و أنا الآن افهم مقصد هذه الدراسة

- I have asked all the questions I wanted to about the study ☐

قد سألت كل الأسئلة التي أردت أن تجاوب عن هذه الدراسة

- I am happy to take part in this research ☐

إني أوافق أن أشترك في هذه الدراسة

- I understand what is required of me and agree for the eye-tracker to be used while I read, and for my voice to be recorded while reading the single words ☐

إني أفهم ما هو مطلوب مني و أوافق أن يستخدم جهاز مراقبة العينين أثناء القراءة وان يسجل صوتي أثناء قراءة الكلمات

- I know I can stop participating and leave at any time without having to give any reasons and without losing any of my rights ☐

أنا أعلم أنه يمكنني أن أتوقف عن المشاركة في هذه الدراسة و أن أغادر في أي وقت دون الحاجة لتقديم أية أسباب و دون أن أفقد أياً من حقوقي

Appendix 3 Cont.

- I do not mind giving my email address and/or telephone number to the researcher so that they can contact me to invite me to participate in future research. I understand that I do not have to give such details if I do not want to. I understand that the researcher would keep my details safely and securely and would not share them with any other parties. ☐

  لا أمانع أن اترك عنوان بريدي الالكتروني أو رقم الهاتف الخاص بي للباحث ليتمكن من أن يدعوني للمشاركة في دراسات أخرى في المستقبل. أنا أعلم أني غير مرغم على ترك هذه المعلومات لو لم أرغب في ذلك. أنا أعلم أن الباحث سوف يقوم بحفظ هذه المعلومات في مكان آمن ولن يعطي هذه المعلومات لأي جهة أخري.

  Email address and/or telephone number/ عنوان البريد الالكتروني أو/ و رقم الهاتف

____

*** *** *** ***

Name/الاسم____

Signature/التوقيع____

Date/التاريخ____

References

Abel, L. A., Troost, B. T., & Dell'Osso, L. F. (1983). The effects of age on normal saccade characteristics and their variability. *Vision Research*, *23*, 33-37. doi:10.1016/0042-6989(83)90038-X

Abu-Rabia, S. (1996). The role of vowels and context in reading of highly skilled native Arabic readers. *Journal of Psycholinguistic Research*, *25*, 629-641. doi:10.1007/BF01712413

Abu-Rabia, S. (1997a). Reading in Arabic orthography: The effect of vowels and context on reading accuracy of poor and skilled native Arabic readers. *Reading and Writing: An Interdisciplinary Journal*, 9, 65-78. doi:10.1023/A:1007962408827

Abu-Rabia, S. (1997b). Reading in Arabic orthography: The effect of vowels and context on reading accuracy of poor and skilled native Arabic readers in reading paragraphs, sentences and isolated words. *Journal of Psycholinguistic Research, 26*, 465-482. doi:10.1023/A:1025034220924

Abu-Rabia, S. (1998). Reading Arabic texts: Effects of text type, reader type, and vowelization. *Reading and Writing: An Interdisciplinary Journal*, 10, 106–119. doi:10.1023/A:1007906222227

Abu-Rabia, S. (1999). The effect of Arabic vowels on the reading comprehension of second- and sixth-grade native Arab children. *Journal of Psycholinguistic Research*, *28*, 93-101. doi:10.1023/A:1023291620997

Abu-Rabia, S. (2002). Reading in a root-based-morphology language: the case of Arabic. *Journal of Research in Reading*, *25*, 299-309. doi:10.1111/1467-9817.00177

Abu-Rabia, S. (2007). The role of morphology and short vowelization in reading Arabic among normal and dyslexic readers in grades 3, 6, 9, and 12. *Journal of Psycholinguistic Research*, *36*, 89-106. doi:10.1007/s10936-006-9035-6

Almabruk, A. A. A., McGowan, V. A., White, S. J., Jordan, T. R., & Paterson, K. B. (2011, August). *Reading Arabic text: effects of word length on landing position and fixation duration*. Poster session presented at 16th European Conference on Eye Movements, Université de Provence, Marseille, France.

Aro, M., & Wimmer, H. (2003). Learning to read: English in comparison to six more regular orthographies. *Applied Psycholinguistics*, *24*, 621-635. doi:10.1017/S0142716403000316

Ashby, J. (2006). Prosody in skilled silent reading: evidence from eye movements. *Journal of Research in Reading*, *29*, 318-333. doi:10.1111/j.1467-9817.2006.00311.x

Ashby, J. & Clifton, C. (2005). The prosodic property of lexical stress affects eye movements during reading. *Cognition*, *96*, B89-B100. doi:10.1016/j.cognition.2004.12.006

Ashby, J., & Rayner, K. (2004). Representing syllable information during silent reading: Evidence from eye movements. *Language and Cognitive Processes*, *19*, 391-426. doi:10.1080/01690960344000233

Ashby, J., Rayner, K., & Clifton, C. (2005). Eye movements of highly skilled and average readers: Differential effects of frequency and predictability. *Quarterly Journal of Experimental Psychology, 58A*, 1065-1086. doi:10.1080/02724980443000476

Ashby, J., Treiman, R., Kessler, B., & Rayner, K. (2006). Vowel processing during silent reading: evidence from eye movements. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 416-424. doi:10.1037/0278-7393.32.2.416

Balota, D. A., Pollatsek, A., & Rayner, K. (1985). The interaction of contextual constraints and parafoveal visual information in reading. *Cognitive Psychology*, *17*, 364–390. doi:10.1016/0010-0285(85)90013-1

Beck, I. L. (1998). Understanding beginning reading: a journey through teaching and research. In J. Osborn & F. Lehr (Eds.), *Literacy for all: issues in teaching and learning* (pp.11-31). New York: Guilford Press.

Beck, I. L. (2006). *Making sense of phonics*. New York: Guilford Press.

Binder, C. V. (1988). Precision teaching: Measuring and attaining exemplary academic achievement. *Youth Policy*, *10*(7), 12-15. Retrieved from http://www.binder-riha.com/pt_measuring%2Battaining.pdf

Binder, C. V. (1996). Behavioral fluency: Evolution of a new paradigm. *The Behaviour Analyst*, *19*, 163-197. Retrieved from http://www.binder-riha.com/Evolution_Binder1996.pdf

Binder, C. V. (2003). Doesn't everybody need fluency? *Performance Improvement*, *42*(3), 14-20. Retrieved from http://www.binder-riha.com/Need_Fluency.pdf

Binder, K. S., Pollatsek, A., & Rayner, K. (1999). Extraction of information to the left of the fixated word in reading. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 1162–1172. doi:10.1037/0096-1523.25.4.1162

Blythe, H. I., Häikiö, T., Bertram, R., Liversedge, S. P., Hyönä, J. (2011). Reading disappearing text: Why do children refixate words? *Vision Research*, *51*, 84-92. doi:10.1016/j.visres.2010.10.003

Blythe, H. I., & Joseph, H. S. S. L. (2011). Children's eye movements during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 643-662). Oxford, England: OUP.

Blythe, H. I., Liversedge, S. P., Joseph, H. S. S. L., White, S. J., Findlay, J. M., & Rayner, K. (2006). The binocular co-ordination of eye movements during reading in children and adults. *Vision Research*, *46*, 3898-3908. doi:10.1016/j.visres.2006.06.006

Blythe, H. I., Liversedge, S. P., Joseph, H. S. S. L., White, S. J., & Rayner, S. P. (2009). Visual information capture during fixations in reading for children and adults. *Vision Research*, *49*, 1583-1591. doi:10.1016/j.visres.2009.03.015

Bohannon, J. (2011). Social science for pennies. *Science*, *334*, 307-307.

Bos, C., Mather, N., Dickinson, S., Podhajski, B., & Chard, D. (2001). Perceptions and knowledge of preservice and inservice educators about early reading instruction. *Annals of Dyslexia*, *51*, 97-120. doi:10.1007/s11881-001-0007-0

Boudelaa, S. & Marslen-Wilson, W. D. (2010). Aralex: A lexical dataase for Modern Standard Arabic. *Behavior Research Methods*, *42*, 481-487. doi:10.3758/BRM.42.2.481

Braze, D., Shankweiler, D., Ni, W., & Palumbo, L. C. (2002). Readers' eye movements distinguish anomalies of form and content. *Journal of Psycholinguist Research*, *31*(1), 25-44. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2850050/pdf/nihms180877.pdf

Bruck, M., Genesee, F., & Caravolas, M. (1997). A cross-linguistic study of early literacy acquisition. In B. A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 145-162). Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Brysbaert, M., Drieghe, D., & Vitu, F. (2005). Word skipping: Implications for theories of eye movement control in reading. In G. Underwood (Ed.), *Cognitive processes in eye guidance* (pp. 53–78). Oxford, UK: Oxford University Press.

Brysbaert, M., & Duyck, W. (2010). Is it time to leave behind the Revised Hierarchical Model of bilingual language after fifteen years of service? *Bilingualism: Language and Cognition, 13*, 359-371. doi:10.1017/S1366728909990344

Brysbaert, M., & Vitu, F. (1998). Word skipping: Implications for theories of eye movement control in reading. In G.Underwood (Ed.), *Eye guidance in reading and scene perception* (pp. 125–148). Oxford, England: Elsevier.

Byrne, B. (2005). Theories of learning to read. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading A Handbook* (pp. 104-119). Oxford: Blackwell Publishing.

Calhoon, M. B. (2005). Effects of peer-mediated phonological skills and reading comprehension program on reading skill acquisition for middle school students with reading disabilities. *Journal of Learning Disabilities*, *38*, 424-433. doi:10.1177/00222194050380050501

Cattell, J. (1886). The time taken up by cerebral operations. *Mind*, *11*, 220-242. Retrieved from http://psychclassics.yorku.ca/Cattell/Time/part1-2.htm

Chaffin, R., Morris, R. K., & Seely, R. E. (2001). Learning new word meanings from context: A study of eye movements. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *27*, 225-235. doi:10.1037//0278-7393.27.1.225

Chapman, S. S., Ewing, C. B., & Mozzoni, M. P. (2005). Precision teaching and fluency training across cognitive, physical and academic tasks in children with traumatic brain injury: A multiple baseline study. *Behavioral Interventions*, *20*, 37-49. doi:10.1002/bin.168

Chase, K. H., Rayner, K., & Well, A. D. (2005). Eye movements and phonological parafoveal preview: effects of reading skill. *Canadian Journal of Experimental Psychology*, *59*, 209-217. doi:10.1037/h0087476

Chen, H.-C., Song, H., Lau, W. Y., Wong, K. F. E., & Tang, S. L. (2003). Developmental characteristics of eye movements in reading Chinese. In C. McBride-Chang & H.-C. Chen (Eds.), *Reading development in Chinese children* (pp. 157–169). Westport, CT: Praeger.

Clifton, C., Jr, & Staub, A. (2011). Syntactic influences on eye movements during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 895-909). Oxford, England: OUP.

Clifton, C., Jr, Staub, A., & Rayner, K. (2007). Eye movements in reading words and sentences. In R. van Gompel, M. H. Fischer, W. S. Murray, and R. L. Hill (Eds.), *Eye movements: a window on mind and brain* (pp. 341-372). New York: Elsevier.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp. 151-216). London: Academic.

Coltheart, M. (2005). Modeling reading: the dual-route approach. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading A Handbook* (pp. 6-23). Oxford: Blackwell Publishing.

Cunningham, A. E., Perry, K. E., Stanovich, K. E., & Share, D. L. (2002). Orthographic learning during reading: examining the role of self-teaching. *Journal of Experimental Child Psychology*, *82*(3), 185-199. doi:10.1016/S0022-0965(02)00008-5

Deutsch, A. & Bentin, S. (2001). Syntactic and semantic factors in processing gender agreement in Hebrew: Evidence from ERPs and eye movement. *Journal of Memory and Language*, *45*, 200-224. doi:10.1006/jmla.2000.2768,

Drieghe, D. (2008). Foveal processing and word skipping during reading. *Psychonomic Bulletin & Review*, *15*, 856-860. doi:10.3758/PBR.15.4.856

Drieghe, D. (2011). Parafoveal-on-foveal effects on eye movements during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 839-855). Oxford, England: OUP.

Drieghe, D., Brysbaert, M., Desmet, T., & Debaecke, C. (2004). Word skipping in reading: On the interplay of linguistic and visual factors. *European Journal of Cognitive Psychology*, *16*, 79–103. doi:10.1080/09541440340000141

Drieghe, D., Desmet, T., & Brysbaert, M. (2007). How important are linguistic factors in word skipping during reading? *British Journal of Psychology*, *98*,157–171. doi:10.1348/000712606X111258

Drieghe, D., Rayner, K., & Pollatsek, A. (2005). Eye movements and word skipping during reading revisited. *Journal of Experimental Psychology*, *31*, 954-969. doi:10.1037/0096-1523.31.5.954

Drieghe, D., Rayner, K., & Pollatsek, A. (2008). Mislocated fixations can account for parafoveal-on-foveal effects in eye movements during reading. *The Quarterly Journal of Experimental Psychology*, *61*, 1239-1249. doi:10.1080/17470210701467953

Duffy, S. A., Morris, R. K., & Rayner, K. (1988). Lexical ambiguity and fixation times in reading. *Journal of Memory and Language, 27,*429-446. doi:10.1016/0749-596X(88)90066-6

Ehri, L. C. (1998). Grapheme-phoneme knowledge is essential for learning to read words in English. In J. Metsala & L. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 3-40). Mahwah, NJ: Erlbaum.

Ehri, L. C. (2002). Phases of acquisition in learning to read words and implications for teaching. In R. Stainthrop, P. Tomlinson (Eds.), *Learning and teaching reading* (pp. 7-28). London: British Journal of Educational Psychology: Monograph Series II.

Ehri, L. C. (2005). Development of sight word reading: Phases and findings. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading A Handbook* (pp. 135-154). Oxford: Blackwell Publishing.

Ehri, L. C., Nunes, S. R., Stahl, S. A., & Willows, D. M. (2001). Systematic phonics instruction helps students learn to read: evidence from the National Reading Panel's meta-analysis. *Review of Educational Research*, *71*, 393-447. doi:10.3102/00346543071003393

Ehrlich, S. F., & Rayner, K. (1981). Contextual effects on word perception and eye movements during reading. *Journal of Verbal Learning and Verbal Behavior*, *20*, 641–655. doi:10.1016/S0022-5371(81)90220-6

Ellis, N. C., & Hooper, A. M. (2001). Why learning to read is easier in Welsh than in English: orthographic transparency effects evidenced with frequency-matched tests. *Applied Psycholinguistics*, *22*, 571-599. doi:10.1017/S0142716401004052

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behaviour Research Methods*, *39*, 175-191. doi:10.3758/BF03193146

Ferrand, L., & Grainger, J. (2003). Homophone interference effects in visual word recognition. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, *56*, 403-419. doi:10.1080/02724980244000422

Ferreira, F., & Henderson, J.M. (1991). How is verb information used during syntactic parsing? In G. B. Simpson (Ed.), *Understanding word and sentence* (pp. 305-330). Amsterdam: North-Holland.

Field, A. (2009). *Discovering statistics using SPSS* (3rd Edition). London: Sage.

Filik, R., Paterson, K. B., & Liversedge, S. P. (2005). Parsing with focus particles in context: eye movements during the processing of relative clause ambiguities. *Journal of Memory and Language*, *53*, 473-495. doi:10.1016/j.jml.2005.07.004

Filik, R., Paterson, K. B., & Sauermann, A. (2011). The influence of focus on eye movements during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 925-941). Oxford, England: OUP.

Findlay, J. M., & Glichrist, I. D. (2003). *Active vision the psychology of looking and seeing*. Oxford, UK: OUP.

Fitzsimmons, G., & Drieghe, D. (2011). The influence of number of syllables on word skipping during reading. *Psychonomic Bulleting & Review*, *18*, 736-741. doi:10.3758/s13423-011-0105-x

Foorman, B.R., Francis, D.J., Fletcher, J.M., Schatschneider, C., & Mehta, P. (1998). The role of instruction in learning to read: Preventing reading failure in at-risk children. *Journal of Educational Psychology*, *90*, 37-55. Retrieved from http://www.fcrr.org/science/pdf/Foorman/Foorman_Role_of_Instruction.pdf

Frazier, L., & Rayner, K. (1982). Making and correcting errors during sentence comprehension: eye movements in the analysis of structurally ambiguous sentences. *Cognitive Psychology*, *14*, 178-210. doi:10.1016/0010-0285(82)90008-1

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia: neuropsychological and cognitive studies of phonological reading* (pp. 301-330). London: Erlbaum.

Frost, R. (in press). Towards a universal model of reading. *Behavioral and Brain Sciences*.

Gernsbacher, M. A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology*, *113*, 256-281. doi:10.1037/0096-3445.113.2.256

Goodman, K. S. (1967). Reading: a psycholinguistic guessing game. *Journal of Reading Specialist*, *6*, 126-135.

Gordon, P. C., Hendrick, R., Johnson, M., & Lee, Y. (2006). Similarity-based interference during language comprehension: evidence from eye tracking during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 1304-1321. doi:10.1037/0278-7393.32.6.1304

Gottlob, L. R., Goldinger, S. D., Stone, G. O., & Van Orden, G. C. (1999). Reading homographs: orthographic, phonologic, and semantic dynamics. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 561-574. doi:10.1037/0096-1523.25.2.561

Gough, P. B. (1993). The beginning of decoding. *Reading and Writing: An Interdisciplinary Journal*, *5*, 181-192. doi:10.1007/BF01027483

Häikiö, T., Bertram, R., Hyönä, J., & Niemi, P. (2009). Development of the letter identity span in reading: evidence from the eye movement window paradigm. *Journal of Experimental Child Psychology*, *102*, 167-181. doi:10.1016/j.jecp.2008.04.002

Hammo, B. H. (2009). Towards enhancing retrieval effectiveness of search engines for diacritisized Arabic documents. *Information Retrieval, 12*, 300-323. doi:10.1007/s10791-008-9081-9

Harm, M.W., & Seidenberg, M.S. (1999). Phonology, reading acquisition, and dyslexia: Insights from connectionist models. *Psychological Review*, *106*, 491-528. doi:10.1037/0033-295X.106.3.491

Hartnedy, S. L., Mozzoni, M. P., & Fahoum, Y. (2005). The effect of fluency training on math and reading skills in neuropsychiatric diagnosis children: A multiple baseline design. *Behavioral Intervention*, *20*, 27-36. doi:10.1002/bin.167

Haywood, J. A., & Nahmad, H. M. (1965). *A new Arabic grammar of the written language*. Surrey: Lund Humphries.

Henderson, J. M., & Ferreira, F. (1990). Effects of foveal processing difficulty on the perceptual span in reading: Implications for attention and eye movement control. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *16*, 417-429. doi:10.1037/0278-7393.16.3.417

Hino, Y., & Lupker, S. J. (1996). Effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance*, *22*, 1331-1356. doi:10.1037/0096-1523.22.6.1331

Hino, Y., Lupker, S. J., & Pexman, P. M. (2002). Ambiguity and synonymy effects in lexical decision, naming, and semantic categorization tasks: Interaction between orthography, phonology, and semantics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 686-713. doi:10.1037/0278-7393.28.4.686

Hino, Y., Lupker, S. J., Sears, C. R., & Ogawa, T. (1998). The effects of polysemy for Japanese katakana words. *Reading and Writing*, *10*, 395-424. doi:10.1023/A:1008060924384

Holsgrove, J. V., & Garton, A. F. (2006). Phonological and syntactic processing and the role of working memory in reading comprehension among secondary school students. *Australian Journal of Psychology*, *58*, 111-118. doi:10.1080/00049530600730476

Howell, D. C. (2007). *Statistical methods for psychology* (6th Edition). Belmont, CA: Thomson Wadsworth.

Huestegge, L., Radach, R., Corbic, D., & Huestegge, S. M. (2009). Oculomotor and linguistic determinants of reading development: A longitudinal study. *Vision Research*, *49*, 2948-2959. doi:10.1016/j.visres.2009.09.012

Huey, E. B. (1908/1979). *The psychology and pedagogy of reading* (5th ed.). Cambridge, MA: MIT Press.

Hughes, J. C., Beverley, M., & Whitehead, J. (2007). Using precision teaching to increase the fluency of word reading with problem readers. *European Journal of Behavior Analysis*, *8*, 221-238. Retrieved from http://www.ejoba.org/pdf/2007_2/Hughes_Beverley_Whitehead.pdf

Hulme, C., & Snowling, M. J. (2009). *Developmental disorders of language learning and cognition*. Oxfor, UK: Wiley-Blackwell.

Hyönä, J., & Olson, R. K. (1995). Eye fixation patterns among dyslexic and normal readers: effects of word-length and word-frequency. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *21*, 1430-1440. doi:10.1037/0278-7393.21.6.1430

Hyönä, J. (2011). Foceal and parafoveal processing during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 819-838). Oxford, England: OUP.

Inhoff, A. W., & Liu, W. (1997). The perceptual span during the reading of Chinese text. In H.-C. Chen (Ed.), *The cognitive processing of Chinese and related Asian languages*. Hong Kong: The Chinese University Press.

Inhoff, A. W., & Liu, W. (1998). The perceptual span and oculomotor activity during the reading of Chinese sentences. *Journal of Experimental Psychology: Human Perception and Performance*, *24*, 20–34.

Inhoff, A. W., & Rayner, K. (1986). Parafoveal word processing during eye fixations in reading. *Perception and Psychophysics*, *40*, 431-439. doi:10.3758/BF03208203

Inhoff, A. W., & Topolski, R. (1994). Use of phonological codes during eye fixations and in on-line delayed naming tasks. J*ournal of Memory and Language*, *33*, 689-713. doi:10.1006/jmla.1994.1033

Joseph, H. S. S. L., Liversedge, S. P., Blythe, H. I., White, S., & Rayner, K. (2009). Word length and landing position effects during reading in children and adults. *Vision Research*, *49*, 2078-2086. doi:10.1016/j.visres.2009.05.015

Joseph, H. S. S. L., Liversedge, S. P., Blythe, H. I., White, S. J., Gathercole, S. E., & Rayner, K. (2008). Children's and adults' processing of anomaly and implausibility during reading: Evidence from eye movements. *The Quarterly Journal of Experimental Psychology*, *61*, 708-723. doi:10.1080/17470210701400657

Juhasz, B. J., & Pollatsek, A. (2011). Lexical influences on eye movements in reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 873-893). Oxford, England: OUP.

Juhasz, B. J., Pollatsek, A., Hyönä, J., Drieghe, D., & Rayner, K. (2009). Parafoveal processing within and between words. *The Quarterly Journal of Experimental Psychology*, *62*, 1356-1376. doi:10.1080/17470210802400010

Juhasz., B. J., & Rayner, K. (2003). Investigating the effects of a set of intercorrelated variables on eye fixation durations in reading. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *29*, 1312-1318. doi:10.1037/0278-7393.29.6.1312

Juhasz., B. J., & Rayner, K. (2006). The role of age-of-acquisition and word frequency in reading: Evidence from eye fixation durations. *Visual Cognition*, *13*, 846-863. doi:10.1080/13506280544000075

Juhasz, B. J., White, S. J., Liversedge, S. P., & Rayner, K. (2008). Eye movements and the use of parafoveal word length information in reading. *Journal of Experimental Psychology: Human Perception and Performance, 34,* 1560–1579. doi:10.1037/a0012319

Kelly, B. (2008). *Frameworks for practice in educational psychology: a textbook for trainees and practitioners*. London: Jessica Kingsley Publishers

Kemper, S., Crow, A., & Kemtes, K. (2004). Eye-fixation patterns of high- and low-span young and older adults: Down the garden path and back. *Psychology and Aging*, *19*, 157-170. doi:10.1037/0882-7974.19.1.157

Kennedy, A., & Murray, W. S. (1984). Inspection times for words in syntactically ambiguous sentences under three presentation conditions. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 833-849. doi:10.1037/0096-1523.10.6.833

Kliegl, R., Grabner, E., Rolfs, M., & Engbert, R. (2004). Length, frequency, and predictability effects of words on eye movements in reading. *European Journal of Cognitive Psychology*, *16*, 262-284. doi:10.1080/09541440340000213

Kubina, R. M., & Morrison, R. S. (2000). Fluency in education. *Behavior and Social Issues*, *10*, 83-99. Retrieved from http://frodo.lib.uic.edu/newjournals/index.php/bsi/article/view/112/91

Kubina, R. M., & Starlin, C. M. (2003). Reading with precision. *European Journal of Behavior Analysis*, *4*(1&2), 13-22. Retrieved from http://www.ejoba.org/pdf/2003_1_2/Kubina_et_al.pdf

Kubina Jr., R. M., Ward, M. C., & Mozzoni, M. P. (2000). Helping one person at a time: Precision teaching and traumatic brain injury rehabilitation. *Behavioral Interventions*, *15*, 189-203. doi:10.1002/1099-078X(200007/09)15:3<189::AID-BIN55>3.0.CO;2-X

Kyte, C. S., & Johnson, C. J. (2006). The role of phonological recoding in orthographic learning. *Journal of Experimental Child Psychology*, *93*, 166-185. doi:10.1016/j.jecp.2005.09.003

Lavidor, M., Johnston, R., & Snowling, M. J. (2006). When phonology fails: orthographic neighbourhood effects in dyslexia. *Brain & Language*, *96*, 318-329. doi:10.1016/j.bandl.2005.06.009

Lee, H., Rayner, K., & Pollatsek, A. (1999). The time course of phonological, semantic, and orthographic coding in reading: evidence from the fast priming technique. *Psychonomic Bulletin & Review*, *5*, 624-634. doi:10.3758/BF03212971

Lichacz, F. M., Herdman, C. M., LeFevre, J.-A., & Baird, B. (1999). Polysemy effects in word naming. *Canadian Journal of Experimental Psychology*, *53*, 189-193. doi:10.1037/h0087309

Lingard, T. (1997). Literacy acceleration. *Educational Psychology in Practice*, *12*, 240-249. doi:10.1080/0266736970120410

Lipka, S. (2002). Reading sentences with a late closure ambiguity: Does semantic information help? *Language and Cognitive Processes*, *17*, 271-298. doi:10.1080/01690960143000029

Liversedge, S. P., & Findlay, J. M. (2000). Saccadic eye movements and cognition. *Trends in Cognitive Science*, *4*(1), 6-14. doi:10.1016/S1364-6613(99)01418-7

Liversedge, S. P., Gilchrist, I. D., & Everling S. (2011), *The Oxford Handbook of Eye Movements*. Oxford, England: OUP.

Liversedge, S. P., Paterson, K. B., & Clayes, E. L. (2002). The influence of *only* on syntactic processing of "long" relative clause sentences. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 55A*, 225-240. doi:10.1080/02724980143000253

Liversedge, S. P., Rayner, K., White, S. J., Vergilino-Perez, D., Findlay, J. M., & Kentridge, R. W. (2004). Eye movements while reading disappearing text: Is there a gap effect in reading? *Vision Research*, *44*, 1013–1024. doi:10.1016/j.visres.2003.12.002

Lonigan, C. J., Burgess, S. R., Anthony, J. L. (2000). Development of emergent literacy and early reading skills in preschool children: evidence from a latent variable longitudinal study. *Developmental Psychology*, *36*, 596-613. doi:10.1037/0012-1649.36.5.596

Lupker, S. J. (2005). Visual word recognition: Theories and findings. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading A Handbook* (pp. 39-60). Oxford: Blackwell Publishing.

Marshall, J. C., & Newcombe, F. (1973). Patterns of paralexia: A psycholinguistic approach. *Journal of Psycholinguistic Research*, *2*, 175-199. doi:10.1007/BF01067101

McConkie, G. W., & Rayner, K. (1975). The span of the effective stimulus during a fixation in reading. *Perception & Psychophysics*, *17*, 578-586. doi:10.3758/BF03203972

McConkie, G. W., Zola, D., Grimes, J., Kerr, P. W., Bryant, N. R., & Wolff, P. M., (1991). Children's eye movements during reading. In J. F. Stein (Ed.), *Vision and visual dyslexia* (pp. 251-262). Boston: CRC Press.

McGuffey, W. H. (1879). *McGuffey's first eclectic reader*. New York: American Book.

Merbitz, C. T., Miller, T. K., & Hansen, N. K. (2003). Cueing and logical problem solving in brain trauma rehabilitation: Frequency patterns in clinician and patient behaviors. *European Journal of Behavior Analysis*, *4*(1&2), 45-58. doi:10.1002/1099-078X(200007/09)15:3<169::AID-BIN54>3.0.CO;2-5

Meseguer, E., Carreiras, M., & Clifton, C., Jr (2002). Overt reanalysis strategies and eye movements during the reading of mild garden path sentences. *Memory & Cognition*, *30*, 551-561. doi:10.3758/BF03194956

Metsala, J. L., & Walley, A. C. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. Metsala & L. Ehri (Eds.), *Word recognition in beginning reading* (pp. 89-120). Hillside, NJ: Lawrence Erlbaum Associates Inc.

Miellet, S., & Sparrow, L. (2004). Phonological codes are assembled before word fixation: evidence from boundary paradigm in sentence reading. *Brain & Language*, *90*, 299-310. doi:10.1016/S0093-934X(03)00442-5

Mitchell, D. C., Shen, X., Green, M. J., & Hodgson, T. L. (2008). Accounting for regressive eye-movements in models of sentence processing: A reappraisal of the selective reanalysis hypothesis. *Journal of Memory and Language*, *59*, 266-293. doi:10.1016/j.jml.2008.06.002

Munakata, Y., McClelland, J. L., Johnson, M. H., & Siegler, R. S. (1997). Rethinking infant knowledge: Toward an adaptive process account of successes and failures in object permanence tasks. *Psychological Review*, *104*, 686-713. doi:10.1037/0033-295X.104.4.686

Murray, W. S., & Liversedge, S. P. (1994). Referential context effects on syntactic processing. In C. Clifton, L. Frazier, and K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 359-388). Hillside, NJ: Erlbaum.

Ni, W., Fodor, J. D., Crain, S., & Shankweiler, D. (1998). Anomaly detection: Eye movement patterns. *Journal of Psycholinguistic Research*, *27*, 515-540. doi:10.1023/A:1024996828734

Pammer, K., Hansen, P. C., Kringlebach, M. L., Holliday, I., Barnes, G., Hillebrand, A.,… & Cornelissen, P. L. (2004). Visual word recognition: the first half second. *Neuroimage*, *22*, 1819-825. doi:10.1016/j.neuroimage.2004.05.004

Paterson, K. B., Liversedge, S. P., Filik, R., Juhasz, B. J., White, S. J., & Rayner, K. (2007). Focus identification during sentence comprehension: evidence from eye movements. *Quarterly Journal of Experimental Psychology*, *60*, 1423-1445. doi:10.1080/17470210601100563

Pearlmutter, N. J., Garnsey, S. M., & Bock, K. (1999). Agreement processes in sentence comprehension. *Journal of Memory and Language*, *41*, 427-456. doi:10.1006/jmla.1999.2653

Perfetti, C. A. (1992). The representation problem in reading acquisition. In P.B. Gough, L.C. Ehri, & R. Treiman (Eds.), *Reading acquisition* (pp. 145-174). Hillsdale, NJ: Erlbaum.

Pexman, P. M., & Lupker, S. J. (1999). Ambiguity and visual word recognition: Can feedback explain both homophone and polysemy effects? *Canadian Journal of Experimental Psychology*, *53*, 323-334. doi:10.1037/h0087320

Pexman, P. M., & Lupker, S. J., & Hino, Y. (2002). The impact of feedback semantics in visual word recognition: number-of-features effects in lexical decision and naming tasks. *Psychonomic Bulletin and Review*, *9*, 542-549. doi:10.3758/BF03196311

Pexman, P. M., & Lupker, S. J., & Jared, D. (2001). Homophone effects in lexical decision. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *27*, 139-156. doi:10.1037/0278-7393.27.1.139

Pexman, P. M., & Lupker, S. J., & Reggin, L. D. (2002). Phonological effects in visual word recognition: Investigating the impact of feedback activation. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *28*, 527-584. doi:10.1037/0278-7393.28.3.572

Pickering, M. J., & Traxler, M. (1998). Plausibility and the recovery from garden paths: An eyetracking study. *Journal of Experimental Psychology: Learning, Memory, & Cognition,* 24, 940-961. doi:10.1037/0278-7393.24.4.940

Pollatsek, A., Bolozky, S., Well, A. D., & Rayner K. (1981). Asymmetries in the perceptual span for Israeli readers. *Brain and Language,14,* 174-180. doi:10.1016/0093-934X(81)90073-0

Pollatsek, A., Juhasz, B. J., Reichle, E. D., Machacek, D., & Rayner, K. (2008). Immediate and delayed effects of word frequency and word length on eye movements in reading: A reversed delayed effect of word length. *Journal of Experimental Psychology: Human Perception and Performance*, *34*, 726-750. doi:10.1037/0096-1523.34.3.726

Pollatsek, A., Lesch, M., Morris, R. K., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification and reading. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 148-162. doi:10.1037/0096-1523.18.1.148

Pollatsek, A., Tan, L. H., & Rayner, K. (2000). The role of phonological codes in integrating information across saccadic eye movements in Chinese character identification. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 607-633. doi:10.1037/0096-1523.26.2.607

Ravid, d., & Shlesinger, Y. (2001). Vowel reduction in Modern Hebrew: Traces of the past and current variation. *Folia Linguistica*, *35*, 371-397. doi:10.1515/flin.2001.35.3-4.371, //2001

Rayner, K. (1975). The perceptual span and peripheral cues in reading. *Cognitive Psychology*, *7*, 65-81. doi:10.1016/0010-0285(75)90005-5

Rayner, K. (1979). Eye guidance in reading: Fixation locations within words. *Perception*, *8*, 21–30. doi:10.1068/p080021

Rayner, K. (1986). Eye movements and the perceptual span in beginning and skilled readers. *Journal of Experimental Child Psychology*, *41*, 211-236. doi:10.1016/0022-0965(86)90037-8

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, 124, 372–422.

Rayner, K. (2009). Eye movements and attention in reading, scene perception, and visual search. *The Quarterly Journal of Experimental Psychology*, 62, 1457-1506. doi:10.1080/17470210902816461

Rayner, K., Binder, K. S., Ashby, J., & Pollatsek, A. (2001). Eye movement control in reading: Word predictability has little influence on initial landing positions in words. *Vision Research*, *41*, 943–954. doi:10.1016/S0042-6989(00)00310-2

Rayner, K., Carlson, M., & Frazier, L. (1983). The interaction of syntax and semantics during sentence processing: Eye movements in the analysis of semantically biased sentences. *Journal of Verbal Learning and Verbal Behaviour*, *22*, 358-374. doi:10.1016/S0022-5371(83)90236-0

Rayner, K., Cook, A. E., Juhasz, B. J., & Frazier, L. (2006). Immediate disambiguation of lexically ambiguous words during reading: evidence from eye movements. *British Journal of Psychology*, *97*, 467-482. doi:10.1348/000712605X89363

Rayner, K., & Duffy, S. A. (1986). Lexical ambiguity and fixation times in reading: Effects of word frequency, verb complexity, and lexical ambiguity. *Memory and Cognition*, *14*, 191-201. doi:10.3758/BF03197692

Rayner, K., & Fischer, M. H. (1996). Mindless reading revisited: eye movements during reading and scanning are different. *Perception & Psychophysics*, *58*, 734-747. doi:10.3758/BF03213106

Rayner, K., Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2001). How psychological science informs teaching of reading. *Psychological Science in the Public Interest*, *2*(2), 31-74.

Rayner, K. Foorman, B. R., Perfetti, C. A., Pesetsky, D., & Seidenberg, M. S. (2002). How should reading be taught? *Scientific American*, *286*(3), 84-91.

Rayner, K., & Frazier, L. (1987). Parsing temporarily ambiguous complements. *Quarterly Journal of Experimental Psychology*, *39A*, 657-673. doi:10.1080/14640748708401808

Rayner, K., Li, X., Juhasz, B. J., & Yan, G. (2005). The effect of word predictability on the eye movements of Chinese readers. *Psychonomic Bulletin & Review*, *12*, 1089–1093. doi:10.3758/BF03206448

Rayner, K., & Liversedge, S. P. (2004). Visual and linguistic processing during eye fixations in reading. In F. Ferreira and J. Henderson (Eds.) *The interface of language, vision and action: Eye movements and the visual world* (pp. 59-104). New York: Psychology Press.

Rayner, K., & Liversedge, S. (2011). Linguistic and cognitive influences on eye movements during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 751-766). Oxford, England: OUP.

Rayner, K., Liversedge, S. P., & White, S. J. (2006). Eye movements when reading disappearing text: The importance of the word to the right of fixation. *Vision Research*, *46*, 310–323. doi:10.1016/j.visres.2005.06.018

Rayner, K., Liversedge, S. P., White, S. J., & Vergilino-Perez, D. (2003). Reading disappearing text: Cognitive control of eye movements. *Psychological Science*, *14*, 385–389. Retrieved from http://www.jstor.org/stable/pdfplus/40063814.pdf

Rayner, K., & McConkie, G. W. (1976). What guides a reader's eye movements? *Vision Research*, *16*, 829–837. doi:10.1016/0042-6989(76)90143-7

Rayner, K., Murphy, L. A., Henderson, J. M., & Pollatsek, A. (1989). Selective attentional dyslexia. *Cognitive Neuropsychology, 6,* 357-378. doi:10.1080/02643298908253288

Rayner, K., Pollatsek, A., Ashby, J., & Clifton, C. (2012). *Psychology of reading* (2nd ed.). Hove: Psychology Press.

Rayner, K., Raney, G., & Pollatsek, A. (1995). Eye movements and discourse processing. In R.F. Lorch and E.J. O'Brien (Eds), *Sources of coherence in reading* (pp 9-36), Hillsdale, NJ: Erlbaum.

Rayner, K., Reichle,E. D., Stroud, M. J., Williams, C. C., & Pollatsek, A. (2006). The effect of word frequency, word predictability, and font difficulty on the eye movements of young and older readers. *Psychology and Aging*, *21*, 448-465. doi:10.1037/0882-7974.21.3.448

Rayner, K., Sereno, S. C., & Raney, G. E. (1996). Eye movement control in reading: A comparison of two types of models. *Journal of Experimental Psychology: Human Perception and Performance*, *22*, 1188–1200. doi:10.1037/0096-1523.22.5.1188

Rayner, K., Slattery, T. J., Drieghe, D., & Liversedge, S. P. (2011). Eye movements and word skipping during reading: Effects of word length and predictability. *Journal of Experimental Psychology: Human Perception and Performance*, *37*, 514-528. doi:10.1037/a0020990

Rayner, K., Warren, T., Juhasz, B., & Liversedge, S. P. (2004). The effects of plausibility on eye movements in reading. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *30*, 1290-1301. doi:10.1037/0278-7393.30.6.1290

Rayner, K., & Well, A. D. (1996). Effects of contextual constraint on eye movements in reading: A further examination. *Psychonomic Bulletin & Review*, *3*, 504–509. doi:10.3758/BF03214555

Rayner, K., Yang, J., Castelhano, M. S., & Liversedge, S. P. (2011). Eye movements of older and younger readers when reading disappearing text. *Psychology and Aging*, *26*, 214-223. doi:10.1037/a0021279

Ravid, d., & Shlesinger, Y. (2001). Vowel reduction in modern Hebrew: Traces of the past and current variation. *Folia Linguistica*, *35*, 371-397. doi:10.1515/flin.2001.35.3-4.371, //2001

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology*, *81*, 274-280. doi:10.1037/h0027768

Reichle, E. D., Reineberg, A. E., & Schooler, J. W. (2010). Eye movements during mindless reading. *Psychological Science*, *21*, 1300-1310. doi:10.1177/0956797610378686

Reichle, E. D., Pollatsek, A., & Rayner, K. (2012). Using E-Z Reader to simulate eye movements in nonreading tasks: a unified framework for understanding the eye-mind link. *Psychological Review*, *119*, 155-185. doi:10.1037/a0026473

Reingold, E. M., & Rayner, K. (2006). Examining the word identification stages hypothesized by the E-Z Reader model. *Psychological Science*, *17*, 742-746. doi:10.1111/j.1467-9280.2006.01775.x

Reingold, E. M., Yang, J., & Rayner, K. (2010). The time course of word frequency and case alternation effects on fixation times in reading: Evidence for lexical control of eye movements. *Journal of Experimental Psychology: Human Perception and Performance*, 36, 1677-1683. doi:10.1037/a0019959

Rodd, J. M. (2004). The effect of semantic ambiguity on reading aloud: a twist in the tale. *Psychonomic Bulletin and Review*, *11*, 440-445. doi:10.3758/BF03196592

Routman, R. (1991). *Invitations: changing as teachers and learners K-12*. Portsmouth, NH: Heinemann.

Rueckl, J. G., & Seidenberg, M. S. (2009). Computational modelling and the neural bases of reading and reading disorders. In K. Pugh & P. McCardle (Eds.), *How children learn to read: Current issues and new directions in integration of cognition, neurobiology and genetics of reading and dyslexia research and practice* (pp. 101-134). New York: Psychology Press.

Sabisch, B., Hahne, A., Glass, E., von Suchodoletz, W. & Friederici, A. D. (2006). Auditory language comprehension in children with developmental dyslexia: Evidence from event-related brain potentials. *Journal of Cognitive Neuroscience*, *18*, 1676-1695. doi:10.1162/jocn.2006.18.10.1676

Santesteban, M., Pickering, M. J., & McLean, J. F. (2010). Lexical and phonological effects on syntactic processing: Evidence form syntactic priming. *Journal of Memory and Language*, *63*, 347-366. doi:10.1016/j.jml.2010.07.001

Schatschneider, C., Fletcher, J. M., Francis, D. J., Carlson, C. D., & Foorman, B. R. (2004). Kindergarten prediction of reading skills: a longitudinal comparative analysis. *Journal of Educational Psychology*, *96*, 265-282. doi:10.1037/0022-0663.96.2.265

Schiff, R. & Ravid, D. (2007). Morphological analogies in Hebrew-speaking university students with dyslexia compared to typically developing gradeschoolers. *Journal of Psycholinguistic Research*, *36*, 237-253. doi:10.1007/s10936-006-9043-6

Schultz, E. (2004). *A student grammar of Modern Standard Arabic*. Cambridge: CUP.

Sereno, S. C., O'Donnell, P. J., & Rayner, K. (2006). Eye movements and lexical ambiguity resolution: investigating the subordinate-bias effect. *Journal of Experimental Psychology: Human Perception and Performance*, *32*, 335-350. doi:10.1037/0096-1523.32.2.335

Sereno, S. C., & Rayner, K. (2000). Spelling-sound regularity effects on eye fixations in reading. *Perception & Psychophysics*, *62*, 402-409. doi:10.3758/BF03205559

Service, E., Ferrari, M., & Palladino, P. (2011). Effects of phonological and lexical stress on serial recall of pseudowords. *Canadian Journal of Experimntal Psychology – Revue De Psychologie Experimentale*, *65*, 318-319.

Seymour, P.H.K., Aro, M., & Erskine, J.M.(2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology*, *94*,143-174. doi:10.1348/000712603321661859

Seymour, P. H. K., & Duncan, L. G. (2001). Learning to read in English. *Psychology: The Journal of the Hellenic Psychological Society*, *8*, 281-299.

Shankweiler, D., Lundquist, E., Dryer, L. G., & Dickinson, C. C. (1996). Reading and spelling difficulties in high school students: causes and consequences. *Reading and Writing*, *8*, 267-294. doi:10.1007/BF00420279

Share, D. L. (1995). Phonological recoding and self-teaching: sine qua non of reading acquisition. *Cognition*, *55*, 151-218. doi:10.1016/0010-0277(94)00645-2

Share, D. L. (1999). Phonological recoding and orthographic learning: a direct test of the self-teaching hypothesis. *Journal of Experimental Child Psychology*, *72*, 95-129. doi:10.1006/jecp.1998.2481

Share, D. L. (2008). *On the anglocentricities of current reading research and practice: the perils of overreliance on an "outlier" orthography*. *Psychological Bulletin*, *134*, 584-615. doi:10.1037/0033-2909.134.4.584

Share, D. & Levin, I. (1999). Learning to read and write in Hebrew. In M. Harris and G. Hatano (Eds.), *Learning to read and write: A cross-linguistic perspective* (pp. 89–111). Cambridge: CUP.

Share, D. L., & Stanovich, K. E. (1995). Cognitive processes in early reading development: Accommodating individual differences into a model of acquisition. *Issues in Education*, *1*, 1-57.

Smith, F. (1973). *Psycholinguistics and reading*. New York: Holt, Reinhart, & Winston.

Smith, F. (2004). *Understanding reading* (6th ed.). Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Snowden, R., Thompson, P., & Troscianko, T. (2006). *Basic vision an introduction to visual perception*. Oxford, UK: OUP.

Snowling, M. J. (1998). Dyslexia as a phonological deficit: Evidence and implications. *Child and Adolescent Mental Health*, *3*(1), 4-11. doi:10.1111/1475-3588.00201

Snowling, M. J. (2000). *Dyslexia*. Oxford, UK: Blackwell.

Snowling, M. J., Duff, F., Petrou, A., & Schiffeldrin, J. (2011). Identification of children at risk of dyslexia: the validity of teacher judgements using 'Phonic Phases'. *Journal of Research in Reading*, *34*, 157-170. doi:10.1111/j.1467-9817.2011.01492.x

Snowling, M. J., & Göbel, S. M. (2011). Reading development and dyslexia. In U. Goswami (Ed.), *The Wiley-Blackwell handbook of childhood cognitive development* (2nd ed. pp. 524-548). Oxford: Wiley-Blackwell.

Solan, H. A., Feldman, J., & Tujak, L. (1995). Developing visual and reading efficiency in older adults. *Optometry and Vision Science*, *72*, 139-145. Retrieved from http://journals.lww.com/optvissci/Abstract/1995/02000/Developing_Visual_and_Reading_Efficiency_in_Older.12.aspx

Staub, A., White, S. J., Drieghe, D., Hollway E. C., & Rayner, K. (2010). Distributional effects of word frequency on eye fixation durations. *Journal of Experimental Psychology: Human Perception and Performance*, *36*, 1280-1293. doi:10.1037/a0016896

Storch, S. A., & Whitehurst, G. J. (2002). Oral language and code-related precursors to reading: evidence from a longitudinal structural model. *Developmental Psychology*, *38*, 934-947. doi:10.1037/0012-1649.38.6.934

Taylor, S. E. (1965). Eye movements while reading: Facts and fallacies. *American Educational Research Journal*, *2*, 187-202. Retrieved from http://www.jstor.org/stable/1161646

Traxler, M., Pickering, M., & Clifton, C., Jr (1998). Adjunct attachment is not a form of lexical ambiguity resolution. *Journal of Memory and Language*, *39*, 558-592. doi:10.1006/jmla.1998.2600

Trost, S., & Gruber, O. (2012). Evidence for a double dissociation of articulatory rehearsal and non-articulatory maintenance of phonological information in human verbal working memory. Neuropsychobiology, 65(3), 133-140. doi:10.1159/000332335

Trueswell, J., Sekerina, I., Hill, N., & Logrip, M. (1999). The kindergarten-path effect: Studying online sentence processing in young children. *Cognition*, *73*, 89-134. doi:10.1016/S0010-0277(99)00032-3

Uzzaman, S., & Joordens, S. (2011). The eyes know what you are thinking: eye movements as an objective measure of mind wandering. *Consciousness and Cognition*, *20*, 1882-1886. doi:10.1016/j.concog.2011.09.010

Van Gompel, R. P. G., Pickering, M., Pearson, J., & Liversedge, S. P. (2005). Evidence against competition during syntactic ambiguity resolution. *Journal of Memory & Language*, *52*, 284-307. doi:10.1016/j.jml.2004.11.003

Van Orden, G. C. (1987). A rows is a rose: Spelling, sound, and reading. *Memory & Cognition*, *15*, 181-198. doi:10.3758/BF03197716

Van Orden, G. C., Johnston, J. C., & Hale, B. L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*, 371-386. doi:10.1037/0278-7393.14.3.371

Van Orden, G. C., & Kloos, H. (2005). The question of phonology and reading. In M. J. Snowling & C. Hulme (Eds.), *The Science of Reading A Handbook* (pp. 61-78). Oxford: Blackwell Publishing.

Van Orden, G. C., Pennington, B. F., & Stone, G. O. (2001). What do double dissociations prove? *Cognitive Science*, *25*, 111-172. doi:10.1207/s15516709cog2501_5

Vitu, F. (2011). On the role of visual and oculomotor processes in reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 731-749). Oxford, England: OUP.

Vitu, F., O'Regan, J. K., Inhoff, A. W., & Topolski, R. (1995). Mindless reading: Eye-movement characteristics are similar in scanning letter strings and reading texts. *Perception and Psychophysics*, *57*, 352–364. doi:10.3758/BF03213060

Vonk, W. (1984). Eye movements during comprehension of pronouns. In A. G. Gale & F. Johnson (Eds.), *Theoretical and applied aspects of eye movement research* (pp. 203–211). Amsterdam: North-Holland.

Vullutino, F. R. & Fletcher, J. M. (2005). Developmental dyslexia. In M. J. Snowling & C. Hulme (Eds.), *The Science of reading a handbook* (pp. 362-378). Oxford: Blackwell Publishing.

Walley, A. C. (1993). The role of vocabulary development in children's spoken word recognition and segmentation ability. *Developmental Review*, *13*, 286-350. doi:10.1006/drev.1993.1015

Warren, T. (2011). The influence of implausibility and anomaly on eye movements during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (pp. 911-923). Oxford, England: OUP.

Warren, T., & McConnell, K. (2007). Investigating effects of selectional restriction violations and plausibility violation severity on eye-movements in reading. *Psychonomic Bulletin and Review*, *14*, 770-775. doi:10.3758/BF03196835

Warren, T., McConnell, K., & Rayner, K. (2008). Effects of context on eye movements when reading about plausible and impossible events. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*, 1001-1010. doi:10.1037/0278-7393.34.4.1001

Wheat, K. L., Cornelissen, P. L., Frost, S. J., & Hansen, P. C. (2010). During visual word recognition, phonology is accessed within 100 ms and may be medicated by a speech production code: evidence from magnetoencephalography. *Journal of Neuroscience*, *30*, 5229-5233. doi:10.1523/JNEUROSCI.4448-09.2010

White, O. R. (1986). Precision teaching – precision learning. *Exceptional Children*, *52*, 522-534. Retrieved from http://courses.washington.edu/edspe510/Downloads/White_PT_PL(small).pdf

White, S. J. (2008). Eye movement control during reading: Effects of word frequency and orthographic familiarity. *Journal of Experimental Psychology: Human Perception and Performance*, *34*, 205-223. doi:10.1037/0096-1523.34.1.205

White, S. J., Rayner, K., & Liversedge, S. P. (2005). The influence of parafoveal word length and contextual constraint on fixation durations and word skipping in reading. *Psychonomic Bulletin & Review, 12,* 466–471. doi:10.3758/BF03193789

Williams, R. S., & Morris, R. K. (2004). Eye movements, word familiarity, and vocabulary acquisition. *European Journal of Cognitive Psychology*, *16*, 312-339. doi:10.1080/09541440340000196

Wilson, L. B., Tregellas, J. R., Slason, E., Pasko, B. E., & Rojas, D. C. (2011). Implicit phonological priming during visual word recognition. *Neuroimage*, *55*, 724-731. doi:10.1016/j.neuroimage.2010.12.019

Wimmer, H., & Goswami, U. (1994). The influence of orthographic consistency on reading development: word recognition in English and German children. *Cognition*, *51*(1), 91-103. doi:10.1016/0010-0277(94)90010-8

Wolff, U. (2009). Phonological and surface subtypes among university students with dyslexia. *International Journal of Disability, Development and Education*, *56*(1), 73-91. doi:10.1080/10349120802682083

Woolfson, L. M. (2011). *Educational psychology: the impact of psychological research on education*. Essex, England: Pearson.

Yan, G., Tian, H., Bai, X., & Rayner, K. (2006). The effect of word and character frequency on eye movements of Chinese readers. *British Journal of Psychology*, *97*, 259-268. doi:10.1348/000712605X70066

Zabell, C., & Everatt, J. (2002). Surface and phonological subtypes of adult developmental dyslexia. *Dyslexia*, *8*, 160-177. doi:10.1002/dys.223

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain-size theory. *Psychological Bulletin*, *131*, 3-29. doi:10.1037/0033-2909.131.1.3