Level 1

Reading, Psychology of

Simon Garrod, University of Glasgow, Glasgow, UK
Meredyth Daneman, University of Toronto, Toronto, Canada

CONTENTS

The psychology of reading investigates the process by which readers extract visual information from written text and make sense of it.

INTRODUCTION

0606.001 Reading is the process by which a reader extracts visual information from a piece of written text and makes sense of it. Psychologists are interested in questions such as how readers extract this visual information, what writing is, how it relates to speech, and precisely how a reader makes sense of the text during reading. Because children have to be taught to read in a way that they do not have to be taught to speak, psychologists are also interested in how we learn to read and what underlies individual differences in reading skill.

0606.002 Consider the following passage:

> Clyde did not want to arouse suspicion. So he sat down in the waiting room with his hand over his holster and smiled politely at the other occupants of the room. He thumbed deliberately through the heaps of reading matter on the table until he spotted the latest *Newsweek*. He opened the magazine and then carefully counted the number of bullets it held, waiting to be fired. When the office door opened, Clyde was poised and ready. The magazine was full.

0606.003 This passage is made up of a series of graphical symbols (e.g. letters, words, sentences) that represent a word-by-word transcription of its spoken form. Although all writing systems use graphical symbols to represent the spoken language, they do so in different ways. For example, in the Japanese Kana writing system, the symbols correspond to whole syllables (e.g. the *wait* + the *ing* sounds in 'waiting'), whereas in English, letters or groups of letters correspond to smaller sound units or *phonemes* (e.g. the *w ai t i ng* sounds in 'waiting'). These different systems pose different problems for readers and those learning to read.

WRITING SYSTEMS AND ORTHOGRAPHIC DEPTH

The three main kinds of writing system are *logographic* systems (as in Chinese and Japanese Kanji), *syllabic* systems (as in Japanese Kana), and *alphabetic* systems (as in English, Greek, and Russian). Logographic systems use symbols to represent word meanings, so the symbols – called 'characters' in Chinese – do not map directly onto any sound segments in the spoken language. As a result, readers have to learn thousands of different characters – almost one for each word – to become literate in Chinese. Syllabaries and alphabets have symbols that map onto whole syllables in the first case or phonemes in the second. Because there are many more syllables than phonemes, syllabaries tend to have more symbols (typically 100) than do alphabets (typically 25 to 30). However, even with alphabetic systems, such as written English or Italian, the transparency of the mapping between the letters in the alphabet and the spoken phonemes varies considerably. For example, in Italian there is a very direct and consistent mapping between *graphemes* (i.e. letters and patterns of letters) and phonemes (i.e. individual speech sounds), whereas in English there is not. Across English words, the same combination of letters may map onto a range of distinct speech sounds (e.g. compare the *ou* sound in the words c*ou*nted and thr*ou*gh in the Clyde passage; now consider en*ou*gh and th*ou*gh). 0606.004

There are various reasons for this difference between the written languages. One reason is that languages like English have tended to import foreign words and retain their original spelling 0606.005

(e.g. *villa*, *centre*). This means that the grapheme-to-phoneme mappings may be inappropriate for English pronunciation. Another reason is that in some written languages the spelling sometimes reflects the *morphemic* or meaning structure of words as opposed to their pronunciation. For example in English, 'vine' and 'vineyard' share the same letter pattern *VINE*, which corresponds to the common meaning component of the two words. However, this pattern of letters is pronounced quite differently in the two spoken words. The degree to which the written language reflects morphology as opposed to phonology is called *orthographic depth*. Written languages like Italian have shallow orthographies, whereas written English has a deep orthography. In general, it is more difficult to learn to read in languages with deep orthographies as opposed to shallow orthographies. Also, alphabetic systems tend to be more difficult to learn than syllabaries.

PHONOLOGICAL RECODING DURING SILENT READING

0606.006 Most readers are aware of covertly pronouncing printed words as they read. Many even report experiencing an inner speech that has the appropriate stress, pauses, and intonation patterns for the text being read. The process of translating print to sound has been called *phonological recoding* (also *phonological encoding*, *speech recoding*, *subvocalization*, *inner speech*). It has been argued that phonological recoding limits reading speed to the rate at which we can covertly articulate the words. Indeed, commercial speed reading courses lure their clients by boasting that they can dramatically increase reading speed at no cost to comprehension simply by teaching people to eliminate phonological recoding. However, some psychologists would argue that phonological recoding serves an important, or even necessary, information-processing function in silent reading so that preventing or limiting inner speech would have an adverse effect on reading comprehension.

0606.007 Psychologists have proposed two possible roles for phonological recoding. According to the first view, readers recode a printed word into the way it sounds as a way of gaining access to the meaning of that word held in memory. So for example, by applying spelling-to-sound rules, the letters *s-a-t* could be mentally converted into their corresponding phonemes /s/ /æ/ /t/, and the phonological code /sæt/ could then be used to access the word's meaning, much as is done during listening comprehension. Evidence for the use of phonological codes to access word meanings comes from demonstrating *homophone* (i.e. words that sound the same) confusion effects. For example, if readers use sound to access meaning, they should be more likely to mistakenly judge a phrase to be sensible if it sounds correct (e.g. 'He thumbed deliberately threw the heaps of reading matter …') than if it does not sound correct (e.g. 'He thumbed deliberately throw the heaps of reading matter …'). Psychologists agree that *prelexical* phonological codes are particularly important for beginning readers and unskilled readers who will frequently encounter words that are unfamiliar to them in print (but familiar if recoded into sound). However, psychologists are in some disagreement as to whether fluent adult readers generate prelexical phonological codes during silent reading, or whether they access the meanings of words directly on the basis of the words' visual features. Some researchers argue that skilled readers use the direct visual pathway, others argue that skilled readers use the indirect phonologically mediated pathway, and yet others argue for dual (alternate) pathways to the lexicon.

0606.008 Regardless of the extent to which skilled readers engage in prelexical phonological recoding, at least some of the inner speech of a skilled reader must be generated *after* lexical access because there is no way to know the appropriate stress and intonation patterns without first interpreting the sentence at several levels, such as determining what the individual words mean and doing at least some preliminary analysis of how the words are semantically and syntactically related to one another. The second view of phonological recoding is that phonological codes are generated after lexical access to help the reader to retain information in working memory (temporary memory) long enough for the higher-level semantic integration to occur. During reading, sequences of words must he held in a temporary storage buffer while the comprehension processes integrate them into a meaningful conceptual structure that can be stored in a more permanent memory. For example, when first encountering the Clyde passage, most readers probably initially interpreted the word 'magazine' to mean 'reading periodical' because this is the meaning that was strongly primed by the preceding context ('… he spotted the latest *Newsweek*'). However, this meaning is inconsistent with the subsequent text ('the number of bullets it held, waiting to be fired'), and a resolution of the apparent inconsistency requires a reinterpretation of

'magazine' to mean 'bullet chamber'. If recently processed information cannot be stored at least temporarily, the reader would be continually backtracking to reread parts or even whole sentences and passages. It has been argued that the most stable code in working memory is a sound-based one. By generating speech-based (phonological) codes that are less vulnerable to memory loss, the reader can keep track of exact words rather than rough meanings. Thus, according to this second view, phonological recoding plays an important role in reading by facilitating the storage and integration of successive ideas in a text. Evidence for this view comes from demonstrating that comprehension suffers when readers are required to engage in a concurrent task that interferes with the generation or maintenance of phonological codes in working memory. For example, repeating an irrelevant word such as 'cola, cola, cola' during reading has adverse effects on comprehension, whereas engaging in an equally effortful nonverbal finger-tapping task does not.

METHODS FOR STUDYING READING

0606.009 There are two approaches to the study of the reading process itself. The first is to investigate what is remembered after reading a text. This can tell us what information a reader gleans from a text and how long it is retained. For example, memory tests show that readers quickly forget the precise wording of a text as they read it, yet they retain the gist. Memory-based measures of reading are called *offline measures* because they cannot address directly the moment-by-moment decisions a reader makes as he or she is actually reading. For this reason offline measures are generally only used in combination with other more direct measures to investigate the reading process itself.

0606.010 The second approach is to measure the time readers spend looking at the words and sentences as they read them. Recording a reader's eye-movement patterns as they read is the most direct method. Less direct methods use self-paced reading procedures, which let the participant determine the rate at which written material is presented to them. The reader might be required to pace himself or herself sentence by sentence, phrase by phrase, or word by word. For example, in the word-by-word procedure, a word is presented, and as soon as the reader has understood it, he or she presses a key to trigger presentation of the next word. The sequence is then repeated until all the text has been read and the time taken to read each word is recorded. Eye-tracking and self-paced reading produce *online measures*, because they reflect the moment-by-moment processing of the text.

0606.011 During reading the eye moves in a systematic way. There are brief fixations in which gaze stays on the same letter for between 100 and 450 milliseconds. These are interspersed with fast movements called *saccades* during which the gaze moves to another letter or word of the text. Typically, saccades take only 30 milliseconds to execute and change the position of gaze by about eight letter spaces in the text. For a skilled reader, nine out of 10 saccades move the gaze from left to right to sample new material from the text, whereas one out of 10 saccades return the point of gaze to previously read material (these are called *regressions*). Thus, skilled readers typically view all the content words in a text and typically view them in the order that they would occur if spoken. The duration of fixations and the length and direction of saccades (i.e. forward or backward movement of the gaze) directly reflect the ease or difficulty of the reading process. Furthermore, they indicate the precise word in the text that is causing reading difficulty because attention is only given to the word currently fixated.

0606.012 The limited span of attention during reading can be demonstrated using the *moving window* technique in which a computer program controls dynamically the window of text presented to the reader as a function of where they are fixating. For example, with an asymmetric 12-character window, the four characters to left and the eight characters to the right of where the reader is fixating will be displayed as normal, whereas all the remaining text will be converted into random letters. The window of text together with its surround of random letters then changes as the point of fixation changes (see Figure 1). The window changes do not interfere with normal reading because they occur during saccadic eye movements when no information is taken in from the visual stimulus. As a consequence, readers do not notice that the text in front of them is changing as their eyes move across it.

0606.013 With the moving window technique, one can reduce the size and form of the text window and measure when it begins to affect reading rate. It turns out that normal reading is quite possible when the window contains only the word currently fixated plus the first three letters of the next word on the line. However, there is a proviso that the material around the window must retain the spaces between the words in the original text. When the window arrangement is reversed so that the

window contains random letters and the surround contains the normal text, readers encounter difficulty. With a reverse window of only 11 letters in width, reading becomes almost impossible.

0606.014 Moving window studies indicate that readers take in information from only a very limited region at any time during reading. This means that any extra time spent fixating the region must reflect processing difficulty associated with that region of text or previous regions' text not completely processed but still held in memory. Current theories of eye-movement control assume that the programming of where the fixation is to land next is determined on the basis of information about the gross shape of words and spaces to the right of the fixation. This explains why it is important to retain the spaces outside the moving window. In contrast, the decision as to when to launch the eye movement is determined by more immediate processing considerations, such as recognition of the word currently being fixated.

0606.015 Eye-movement studies confirm that the basic identification of each word and its meaning often occurs during the very first fixation on the word. For example, the first fixation duration is affected by the frequency of the word and whether or not it is ambiguous.

SEMANTIC INTERPRETATION AND INTEGRATION

0606.016 Moving window experiments demonstrate that words are identified and semantic information extracted before the eye moves on to the next word in a text. But is all this information integrated into the current interpretation immediately or are some processes delayed? The relationship between sampling and processing time is captured by what is called the immediacy hypothesis. The *immediacy hypothesis* states that each word in a text is processed to the deepest level possible (i.e. in relation to its meaning, how it relates to the context, and so on) before the reader goes on to the next word.

0606.017 In general, this hypothesis has been supported. Evidence for immediate contextual effects on semantic interpretation comes from eye-tracking studies in which people read ambiguous words in different contexts. Consider, for example, interpreting the ambiguous word 'magazine' in the Clyde passage. 'Magazine' has a dominant meaning (i.e. periodical) and a less dominant meaning (i.e. bullet chamber). Eye-tracking studies show that when the prior context favours the less dominant meaning (i.e. bullet chamber), readers spend longer fixating the word than when the context favours either the dominant meaning (i.e. periodical) or neither meaning in particular. This suggests that the contextually appropriate meaning of the word is identified before the reader moves on to the next word in the text. Other findings relate to interpreting what are called *anaphors*. These are expressions such as the pronoun 'he' in the Clyde passage whose interpretation depends upon something that has been previously mentioned in the text (i.e. the antecedent mention of 'Clyde'). The difficulty of establishing the appropriate antecedent is reflected in the time spent reading the anaphor itself and the words that immediately follow it. This indicates that at least some aspects of the interpretation of the anaphoric pronoun occur as soon as it is encountered in the text.

0606.018 However, there is also evidence that some semantic processing and integration is left until the reader has completed a whole clause or sentence of text. Hence, readers tend to spend a little extra time looking at the words at the end of a sentence before proceeding to the beginning of the next sentence in the text. This process is sometimes referred to as *sentence wrap-up*.

INDIVIDUAL DIFFERENCES IN READING ABILITY

0606.019 There are large individual differences in how well people read. Some adults can read only 150 words a minute whereas others can read 400 words a minute or more. Differences in comprehension ability can be just as large. Good readers not only understand the literal facts in a passage, but they also make the appropriate inferences, attend to how the passage is organized, and appreciate the author's tone and style. By contrast, poor readers may read an entire passage without understanding or retaining even the main point. What accounts for the enormous differences in how fast and how accurately people can read? Because reading is a complex cognitive skill that draws on many component processes and resources, any of the component processes has the potential for being a source of individual differences in reading ability. Many – but not all – are. Here we consider some factors that do and do not account for the range of reading ability differences that might be encountered in a typical school or university classroom.

0606.020 Eye-movement control is one component of reading that does not appear to account for individual differences in reading ability. It is not that poor readers display the same pattern of eye movements

and fixations as good readers. On the contrary; they make more and longer fixations than do good readers, as well as many more regressions. However, training poor readers to make the eye-movement patterns of good readers does not lead to concomitant improvements in their comprehension. Consequently, the erratic and inefficient eye movements of poor readers are thought to be the *result* rather than the *source* of their reading problems. Low-level visual-perceptual processes also do not appear to account for individual differences in reading ability because good and poor readers do not differ in the amount of information they can extract during a single eye fixation. Indeed, almost all reading problems are due to difficulties in recognizing words and comprehending language.

0606.021 There is relatively strong evidence that word recognition skills contribute to overall reading ability. Poor readers are slower and less efficient at recognizing written words, slower at accessing word meanings from memory, and less skilled at deriving phonology from print. However, the relationship between word recognition skills and reading ability is much stronger for young readers than it is for adults. For example, the speed with which readers can access word meanings from memory accounts for only about 10 per cent of the variance in reading ability found in a typical university classroom, and is more related to reading fluency than to reading comprehension.

0606.022 On the other hand, the higher-level language comprehension processes common to both reading and listening account for much more of the variance in reading ability that one finds in a typical university classroom. Poor readers are at a particular disadvantage when they are required to execute a process that involves integrating newly encountered information with information that was encountered earlier in the text or that must be retrieved from long-term memory. For example, poor readers have problems interrelating successive topics and integrating information to derive the overall gist or main theme of a passage. They have more difficulty identifying the antecedent referent for a pronoun (e.g. determining that the pronoun 'it' in 'it held' refers to the magazine of the gun that Clyde opened); they have more difficulty making inferences (e.g. that Clyde's holster contained a gun; that he removed his hand from the holster); and they tend to make fewer thematic inferences spontaneously during reading (e.g. that Clyde may have wanted to murder someone, that he was in a doctor's office, or perhaps a lawyer's office). All in all, poor readers tend not to demand informational coherence and consistency in a text, and they often fail to detect, let alone repair, semantic inconsistencies (e.g. the inconsistency between the initially accessed 'reading periodical' meaning for 'magazine' and the subsequent phrase 'held, waiting to be fired…').

Two mechanisms have been proposed to account 0606.023
for why poor readers have difficulty with the integration processes of reading: *working memory capacity*, and *background knowledge*. According to working memory theories of reading ability, poor readers are at a disadvantage at all of the processes that require the integration of newly encountered information with information encountered *earlier in the text* because they have less capacity to keep the earlier information active in temporary storage. According to knowledge-based theories of reading ability, poor readers are at a disadvantage at all of the processes that require the integration of newly encountered information with information that must be *retrieved from long-term memory*, either because they have less background knowledge of the topic being read, and/or because they have less ability to access that knowledge when required.

The existence of individual differences in read- 0606.024
ing ability has far-reaching educational implications. Because reading is the major medium for acquiring knowledge and skills, poor readers will experience difficulty not only in a literature class, but in classes as diverse as history, economics, and science, as well.

DYSLEXIA

Dyslexia is the term applied to individuals who 0606.025
have a much more severe reading disability than the poor readers described in the previous section, in the sense that these individuals struggle to decode or recognize even the simplest of words. Individuals who were previously competent readers but who suffered an impairment of that ability due to brain injury are said to have *acquired dyslexia*. Individuals who failed to attain normal reading skills in the first place are said to have *developmental dyslexia*.

Acquired dyslexia comes in a number of differ- 0606.026
ent forms. Individuals with *surface dyslexia* appear to have damage to the direct visual pathway to the lexicon, and so they have to rely on the indirect route of assembling the phonological code by applying spelling-to-sound (grapheme-to-phoneme) conversion rules. They can read regular words (e.g. 'sat' and 'hand') and pronounceable nonwords (e.g. 'flum' and 'pib'), but they have difficulty reading words with irregular spelling

patterns (e.g. 'thumbed', 'through'). On encountering the irregular word 'listen', one surface dyslexic misread it as 'liston' (pronouncing the *t* which should be silent), and then added 'the famous boxer' (referring to Sonny Liston, a former boxing champion). The fact that surface dyslexics have a tendency to regularize irregular words (e.g. to say 'liston' for 'listen') and then to ascribe meaning to the words based on how they sound rather than how they look (e.g. to interpret 'listen' as 'Sonny Liston, the boxer') is consistent with the idea that surface dyslexics rely on the indirect phonological route to the lexicon. In contrast, individuals with *phonological dyslexia* appear to have lost their capacity for grapheme-to-phoneme conversions and so they are unable to read pronounceable nonwords and unfamiliar words. However, their direct visual pathway is intact, so they can read (and understand) regular and irregular real words, as long as the words are already familiar to them. Like phonological dyslexics, *deep dyslexics* have lost the capacity for grapheme-to-phoneme conversion (they cannot read nonwords), and must rely on the direct visual route (they can recognize very familiar words). However, deep dyslexics are thought to have multiple sources of damage because they have a number of other difficulties as well. These include difficulty reading familiar function words (e.g. 'the', 'in'), difficulty reading abstract words (e.g. 'suspicion'), and the propensity to make striking semantic substitution errors (e.g. they might read 'ape' as 'monkey' or 'blood' as 'pressure').

0606.027 It has been estimated that approximately 4 per cent of school-aged children have developmental dyslexia in that they have severe difficulty learning to read despite adequate intelligence, vision, and opportunity to learn. Many people are under the misconception that developmental dyslexia is a visual disturbance that manifests itself in the tendency to read letters and words backwards (e.g. to read *d* as *b*, 'was' as 'saw'). However, there is little evidence to support this notion because dyslexic readers make reversal errors no more frequently than beginning readers do. There is still considerable disagreement among psychologists as to the nature of the deficit(s) underlying developmental dyslexia. Nevertheless, there is an emerging consensus that developmental dyslexics do not constitute a homogeneous population, but rather fall into a number of distinct subgroups. Indeed, some researchers have drawn parallels to the different subgroups of acquired dyslexia. For example, approximately 60 per cent of developmental dyslexics are like the phonological dyslexics described earlier, in that they have difficulty assembling a phonological code by applying grapheme-to-phoneme conversion rules. However, there are other developmental dyslexics who are more like the surface dyslexics described earlier, in that they are relatively competent at reading phonologically regular words but have severe problems reading irregular words.

SUMMARY

Reading is a complex skill and particularly so with 0606.028
alphabetic written languages such as English. Although skilled readers can process as many as six words a second, phonological recoding imposes an upper limit on reading rate. Even skilled readers fixate almost all the words in a text and can attend to only one word at a time. Yet, each word is identified rapidly, and, in most cases, its meaning is integrated immediately into the meaning of the passage as a whole.

Since reading is such a complex skill for which 0606.029
we have to receive instruction, it is perhaps not surprising that there are striking individual differences in reading ability. Individual differences arise both within the normal range of readers and in relation to those with specific disabilities such as dyslexia.

Further Reading

Daneman M (1991) Individual differences in reading skills. In: Barr R, Kamil ML, Mosenthal P and Pearson PD (eds) *Handbook of Reading Research*, **vol. 2**, pp. 512–538. White Plains, NY: Longman.

Garrod S and Sanford AJ (1994) Resolving sentences in a discourse context: how discourse representation affects language understanding. In: Gernsbacher M (ed.) *Handbook of Psycholinguistics*, pp. 675–698. New York: Academic Press.

Just MA and Carpenter PA (1987) *The Psychology of Reading and Language Comprehension*. Newton, MA: Allen and Bacon.

Klein RM and McMullen PA (1999) *Converging Methods for Understanding Reading and Dyslexia*. Cambridge, MA: MIT Press.

Rayner K and Pollatsek A (1989) *The Psychology of Reading*. Englewood Cliffs, NJ: Prentice-Hall.

Glossary

Lexical Relating to word forms.

Morpheme (morphological) The smallest meaningful units of language that combine to form words (e.g. the *polite* and the *-ly* components of 'politely').

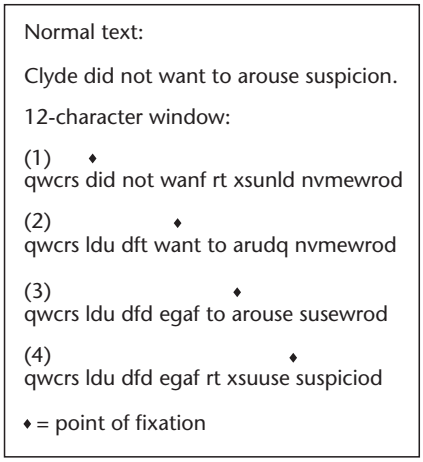
Phoneme (phonological) The smallest interchangeable speech sounds of language that combine to form words.

Semantic Relating to the meaning of words and sentences.

Syntactic Relating to the grammatical structure of sentences.

Keywords: (Check)

Dyslexia; eye movements; immediacy hypothesis; phonological recoding; working memory



0606f001 **Figure 1.** Sequence of presentations for an asymmetric 12-character moving window

ECSaq606
Queries for Macmillan, ECS paper no. 606

Title: Reading, psychology of
Author: Garrod

Section “Phonological recoding”, 2nd para: for the benefit of the elementary-level readership of this article, perhaps briefly define “prelexical”?

And a sentence or two earlier, perhaps also define “homphone”, e.g. “… homophone (i.e. words that sound the same)”?

Section “Methods for studying reading”, 4th para, discussion of figure 1: I think it would be better to follow the wording of the figure and describe this as a 12-character, rather than 12-letter, window (i.e. it includes spaces as well as letters) - OK?

Just and Carpenter ref: please check spelling of publisher: should “Allen” be “Allyn”?