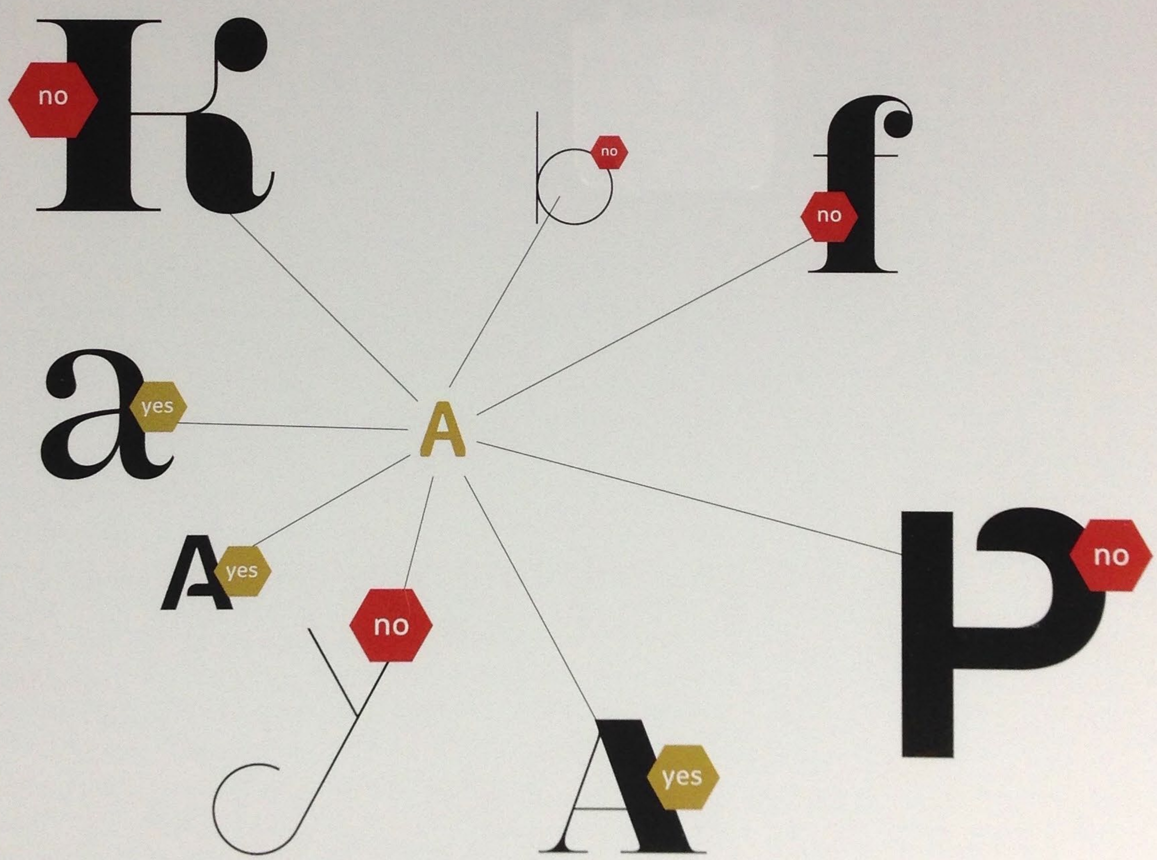
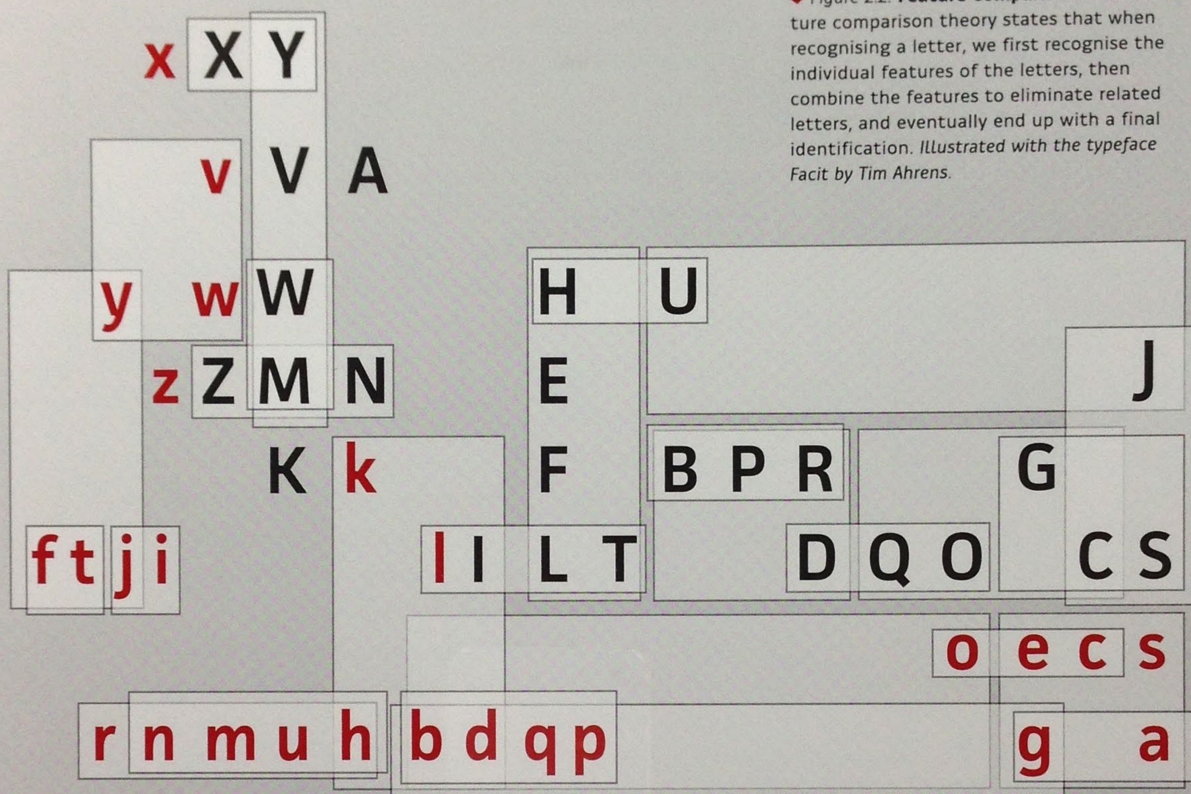
2 Understanding Reading

To define what actually happens when we perceive words and letters is not an altogether easy task. Over the years, scientists have come up with a number of theories to explain the act of reading. These theories range from the one extreme stating that we perceive the words exclusively as wholes without recognising the individual letters[1] to the other extreme stating that reading is based solely on a letter-by-letter recognition process[2].

Although we have yet to fully understand how the brain works when reading, we do have some idea of the general process.

↓ *Figure 2.1.* **Template matching.** According to the template matching theory, all readers have some form of basic master of each letter stored in memory. The question is how we manage to identify letters in very different typefaces and handwriting styles. *Illustrated with Vogue Paris, Ornamenta, A2 BrewTypeDisplay, and A2 Monday, all by Henrik Kubel.*





↓ *Figure 2.2.* **Feature comparison.** The feature comparison theory states that when recognising a letter, we first recognise the individual features of the letters, then combine the features to eliminate related letters, and eventually end up with a final identification. *Illustrated with the typeface Facit by Tim Ahrens.*

Letter identification

There are two main theories on the process of letter identification. The first theory is the template matching theory. The essential idea here is that for each letter of the alphabet, the brain has stored a basic template of the letterform. As we perceive a new shape, the brain flips through a series of templates to find the best match. This is also the theory espoused by type designer Adrian Frutiger[3], who compares the function of reading to a keyhole and its key, where the reader locates the basic skeleton form of the letter, which then fits like a key into the keyhole and triggers identification.

However, the main problem with this theory is explaining how we are capable of recognising the wide variations in typefaces and handwriting that we actually manage to handle. If this were indeed how the system works, the

ODUGQR	IVMXEW
QCDUGO	EWVMIX
CQOGRD	EXWMVI
QUGCDR	IXEMWV
URDGQO	VXWEMI
GRUQDO	MXVEWI
DUZGRO	XVWMEI
UCGROD	MWXVIE
DQRCGU	VIMEXW
QDOCGU	EXVWIM
CGUROQ	VWMIEX
OCDURQ	VMWIEX
UOCGQD	XVWMEI
RGQCOU	XMEWIV
GRUDQO	MXIVEW
OCURDO	VEWMIX
DUCOQG	IVWMEX
CGRDQU	IEVMWX
UDRCOQ	WVZMXE
GQCORU	XEMIWV
GOQUCD	WXIMEV
URDCGO	EMWIVX
GODRQC	IVEMXW

← *Figure 2.3.* **Find the 'z'.** The study by Ulric Neisser found that it is easier to locate the letter 'z' in the left column of letters with visually different features than in the right column of letters with similar features.

brain would have to have a separate template for a flamboyant '𝒜' and a simple sans serif '**A**', and for all variations of handwriting. Even if the brain has some form of clean-up process for letter shapes, it nevertheless seems doubtful that a system like this would be able to decide which parts of a character shape are essential and which are not. The shortcomings of the first theory led to the feature comparison theory.

Instead of perceiving the whole character, this next theory states that the brain decodes the individual features of the character one by one. This analytic process is based on a perception of the characters as a range of disparate features that are gradually combined, until a stage of identification has been reached.

One argument in favour of the feature comparison theory comes from a study on the visual system of cats[4]. By projecting different forms of patterns onto different regions of the cat's retina, the researchers demonstrated that the cortical cells in the cat's visual system fired differently according to whether the stimulus being processed was a horizontal line, a vertical line or a curve. Obviously, there are differences between feline and human visual perception; however, it is commonly accepted that this identification process of lines and curves in the visual cortex is rather similar between the two species. Another finding that supports the feature comparison theory comes from Ulric Neisser[5], who showed that in a search task, test subjects found it easier to locate the letter 'Z' in a group of visually unrelated characters (ODUQRC) than in a group of visually related characters (IVMXWN) *(Fig. 2.3)*. If we read in the way suggested by the template matching theory, the results of this study should show no difference between the unrelated and related character groups. If the eye is searching for one particular template, the shapes of the surrounding templates should be of no importance. However, if we analyse the results by applying the feature comparison theory, searching for the letter 'Z' in a visually related character group means searching among a range of similar features, which would offer a plausible reason for the slowing down of the search process.

However, feature comparison might not be the sole explanation. Another study[6] revealed that fixating an image to the retina, so that when the eye moves the image moves along with the eye, eventually causes the image to disappear *(Fig. 2.4)*. The study found that complex stimuli sometimes disappeared and reappeared as a whole and sometimes vanished in fragments. This suggests that both the template matching and the feature comparison processes play a role, and that they are interrelated in the workings of our perceptual system.

↓ *Figure 2.4.* **Disappearing images.** When we try to hold our eyes still, a slight tremor will always occur; this is essential for our vision. Research shows[6] that if an image is fixated to the eye so that it follows the movement of this tremor, the image will fade and disappear from the retina. This effect may apply to either parts or whole images.

Word superiority effect

In 1886, James McKeen Cattell showed that after a short exposure at a close reading distance, participants were more likely to identify single words than single letters. The phenomenon is known as the word superiority effect. Later, in 1969, another scientist[7] recreated the experiment with a few adjustments, changing the experiment to a forced choice between two target letters that were presented after the stimulus. This was done in such a way that both the two alternative choices would make up a word in connection with parts of the stimulus word *(Fig. 2.5)*. The study found that a target letter in a real word was more accurately recognised than either single letters or a target letter in a nonsense word[8]. On the basis of these findings, it can be hypothesised that reading is based on the long-term recollection of words and word patterns. However, other studies show that this is not exactly the case. When pronounceable nonsense words such as 'mave', or 'reet' are included in experiments based on the forced choice method, studies[9] have found that these words are – in most cases – recognised far better than unpronounceable nonsense words such as 'ftgy', or 'ojhl'. This indicates that the word superiority effect is a result of letter combinations rather than familiar word patterns.

Figure 2.5. **Forced-choice method.** A word, non-word or letter is briefly presented to the participants at a normal reading distance. Next, the participants are presented with a choice between two letters and asked to identify which of the letters was part of the stimulus. *Illustrated with the typeface Beckett by Henrik Kubel.*

HAMBURGEFONT

HamBuRGeFonT

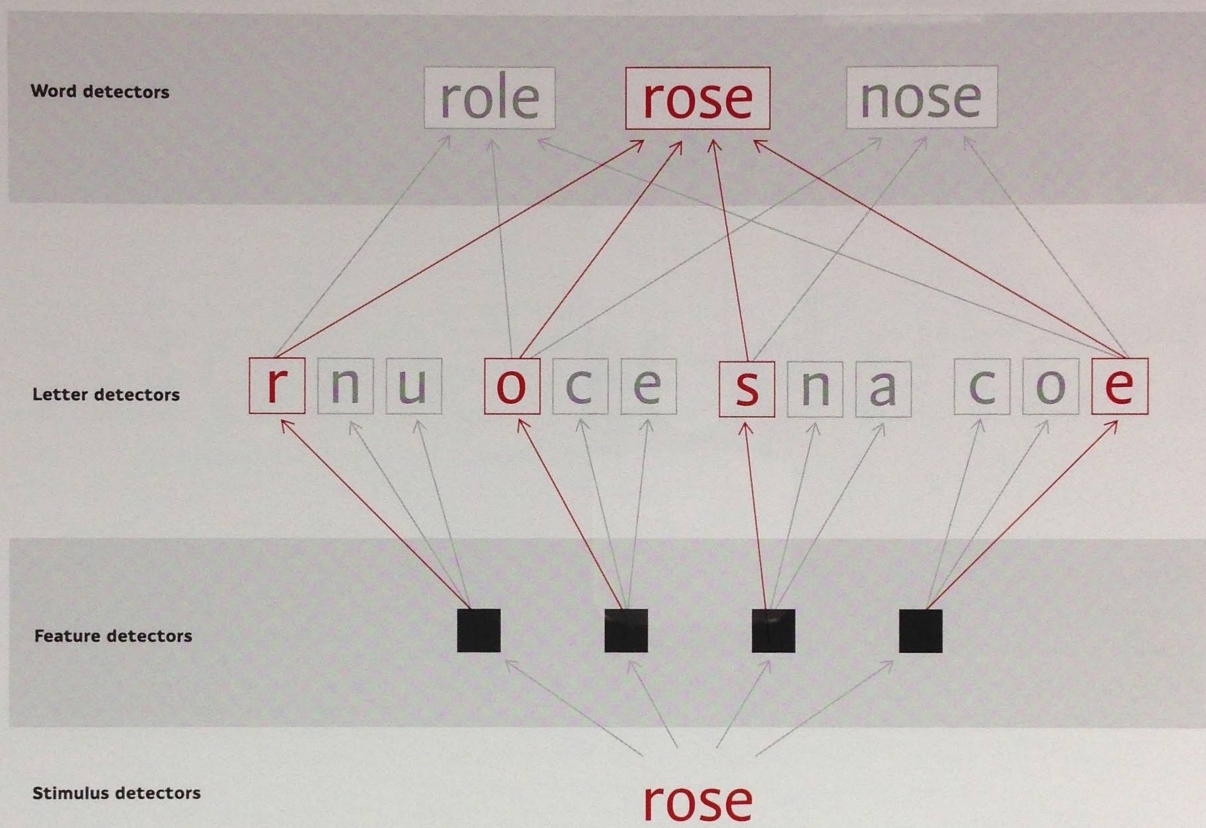
hamburgefont

Word wholes

Many internet users have encountered a circulating text referring to a research project which found that *"it deosn't mttaer waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteres are at the rghit pclae"*. The text further concludes that *"Tihs is bcuseae we do not raed ervey lteter by it slef but the wrod as a wlohe"*. Testing this jumbled word effect, scientists[10] have found that reading speed generally slows down when letters are transposed. If we take a closer look at the text in question, most of the swapping occurs between neighbouring letters, none of the swapped letters create new words, and all the function words such as *it, the, in, a, are*, and *is* stay the same, which makes it easier to guess the content of the sentence. Moreover, if reading is based on word wholes alone – as the text claims – the shifting of ascending and descending letters would break up the word shape and thus undermine our ability to identify the word. One can further assume that the phenomenon will be less prominent when applied to languages with many compound words, such as the Scandinavian languages, German or Dutch.

If we do read by word wholes, words set in mIxEd cAsEs should slow down our reading rate dramatically. Scientists[11] have found, both in reading aloud and in a search task study, that words set in mixed cases where the characters retained their original x- or cap-height sizes did not perform well.

↑ *Figure 2.6.* **Mixed case.** Words set in uppercase and lowercase letters where the height of the letters is adjusted to the same level (top) are easier to recognise than words set in regularly sized mixed letters (middle). *Illustrated with the typeface Neue Swift by Gerard Unger.*



However, it was also found that words set in mixed case where the height of uppercase and lowercase letters was adjusted to the same level performed the same as words set only in uppercase or lowercase letters *(Fig. 2.6)*. Maybe the problem with the unadjusted mixed-case words has more to do with familiarity than with word wholes. Another research project[12] looked into this and found that the performance of mixed-case nonsense words and mixed-case regular words was equally impaired. If in fact our reading is based entirely on whole-word recognition, the performance difference of familiar regular words changed to mixed-case would be radically different from the performance difference of nonsense words changed to mixed-case, since the nonsense words do not contain any familiar word shapes, neither in normal case nor in mixed case.

↑ *Figure 2.7.* **Parallel Letter Recognition (PLR) model.** According to this model, we read by the parallel operation of a bottom-up process, where we identify letter features, and a bottom-down process, where we identify words. *Illustrated with the typeface Stella by Mário Feliciano.*

Parts, wholes and context

Most of the studies reviewed so far do not contradict the basic ideas of the Parallel Letter Recognition (PLR) model[13] *(Fig. 2.7)*. The model contains three basic levels, the first being the feature detector level. As described earlier, the process at this stage involves recognising the features of the individual letters, such as horizontal, vertical, curved and diagonal lines. This information is then passed on to the letter detector level. If an 'o' is part of the stimulus material, the letter detectors for 'o' would be active in combination with letter detectors for other related shapes such as 'c' and 'e'. The task for the letter detectors is to locate the letter with the highest number of common features to match the information received from the feature detector level. The final level involves the word detectors, which in a similar process identify the component features (letters) and combine them into words. What happens next on the word detector level is not yet fully understood[14]. However, it appears that a second process takes place on the word detector level, consisting of the top-down input of some sort of lexical stimulus based on context, word wholes and word parts. This operation in turn proceeds further down to the letter level in a parallel process.

This parallel top-down and bottom-up processing in the PLR model explains the word superiority effect. While single letters have to be identified exclusively by information received from the letter detectors, words are decoded on the basis of information from both letter detectors and word detectors, and therefore, presumably, words will have a higher recognition rate than individual letters. When the perceived word is not identified in the word lexicon, we have to spell out the word, relying on the letter level. If a few letters cannot be identified, the collaboration between the word lexicon and

↓ *Figure 2.8.* **Reading without recognising all letters.** In the corporate identity created by e-types and 2GD for the *Danish Designers*, the letter 'd' is replaced by a square. In spite of knocking out one of the important letters of the Danish language, the text still appears readable.

Our members work within a wi■e variety of in■ustries an■ professional ■isciplines. Historically there is a certain concentration within areas like in■ustrial ■esign/pro■uct ■esign, furniture, textile, interior architecture an■ visual communications/graphic ■esign.

the letter lexicon will serve to identify the word. The model further explains the jumbled word effect; it seems reasonable to assume that as long as there is no phonetic confusion, the collaboration between the predictability delivered by the top-down process and the detailed information of the bottom-up process will be capable of identifying swapped characters, as long as they are not placed too far apart.

So what is the internal relationship between these different processes that influence reading? A recent study by Pelli and Tilman[15] looked into the matter by isolating the three mental processes of *letter-by-letter*, *word-wholes*, and *sentence-context* recognition. The scientists measured reading rates in oral and silent reading of printed text and on text presented in a rapid serial visual process, where the text is displayed word by word at the same position on a screen. The manipulations shown in Figure 2.9 were tested both one at a time and in combinations. The study found that the letter function is the strongest factor, accounting for about 62% of the adult reading rate; the sentence function came in second 22%; while the word function was the weakest of the three, accounting for only 16% of the reading rate. The three processes appear to operate in collaboration.

Combining these findings with the ideas of the PLR model gives us a good indication of the different kinds of operations that take place in the reading process. The collective research suggests that the functions of letter, word, and context detectors support each other by approaching the reading matter from different angles. Although highly dependent on the other detectors, the function of identifying the individual letter comes across as the strongest single factor.

Knock-out	*Examples*
Sentence	**Contribute others. the of Reading measured**
Word	**ThIs text AlTeRnAtEs iN CaSe.**
Letter	**Tbis sartcrec bes Ictfan suhsfitufas.**

↑ *Figure 2.9.* **The test material of the Pelli and Tillman study**. Illustrating the three kinds of 'knock-outs', finding that readers were most troubled when reading the 'letter knock-out'.

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