Space, colour and typography on visual display terminals

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Abstract. Some guidelines are given to meet the observed need for rules about layout, the use of colour and typography on display screens so as to create texts with optimal legibility. Examples of videotex pages are used to illustrate right and wrong layouts, applications of colour and of letter type. The guidelines can be generalized to other types of display such as those used in personal computers and, to a more limited extent, to the use of graphics instead of text. Finally, figures are given on the general public's subjective appreciation of some alternative display layouts.

1. Introduction

This paper may be considered as a companion to that on perceptual limits in VDTs which was recently published in this journal (Van Nes 1984). Whereas the former paper focused on the influence of luminous contrast and character configuration on legibility, the present one will deal with the ways space, colour and typography can be used to maximize text legibility. Being easy to read, texts with a high legibility enable the reader to devote his attention to understanding whatever information the text conveys. The paper has been prompted by the relative scarcity of guidelines in this area: apart from Tinker's classic treatise (1964) on printed text, and the articles by Reynolds (1979) and Long (1984) on text displayed by cathode-ray tubes, not too much appears to have been published on this topic, although there is an evident need for practical guidance, either explicitly expressed, or implicitly demonstrated by the errors which are frequently manifest when text displays are viewed carefully. Such electronic text displays may be edited for a large public, as in videotex, or for a limited number of users, as in personal computing. In both cases, however, the editors often seem to lack the professional knowledge of layout and colour use which is commonplace in the printing industry.

As a predecessor of this paper, an advice was written in 1981 for the Dutch teletext information service which has been broadcast by television since April 1980. With that background, the display examples given here concern texts in the Dutch language. In the meantime, the legibility of teletext in The Netherlands has fortunately improved considerably. The teletext origin of the examples shows up in their format: 24 lines with 40 spaces each of usually bright text on a dark background. Seven colours can be used for text and background, viz. red, green, blue, yellow, magenta, cyan and 'white'. Yellow, magenta, cyan and 'white' in this case are the result of the combined emission from, respectively, the red and green, the red and blue, the green and blue and the red, green and blue phosphors. For this reason, among others, the luminances and brightnesses of these seven colours are unequal.

In the sequel, some basic properties of the visual reading process will be described first. Then, the separate effects of the use of space, colour and typography on legibility will be treated, followed by some illustrations of the combined effect of these image parameters. Finally, some practical guidelines are formulated which mostly apply to multicolour text displays in general and, to a certain extent, may also be generalized to the use of graphics.
2. The visual reading process

In reading, two processes can generally be distinguished (Bouma 1980): firstly, searching for the desired information on the page; secondly, perceiving this information. To maximize legibility, the structure of the page should be such that visual search is rapid and subsequent reading of the passage of interest proceeds without disturbance. While searching, the eyes skim over the page, guided by text attributes such as specific first letters, word lengths etc. and attracted by characters, words or whole areas of a conspicuous nature. In print, sufficient attraction to subheadings etc. may already be provided by bold type, or italics. Such subtle means are not available on many displays; there the text editor has to resort to means like displaying the relevant parts of the text in a different colour. However, they may then be too conspicuous in the rest of the text, and the reader’s attention is involuntarily and continuously distracted after searching. Reading itself may consequently be disturbed.

During undisturbed reading of connected text, the eyes move along the lines of the text in a series of rapid movements, called saccades, alternating with fixation pauses during which information is extracted in the visual reading field, i.e. from 10–20 letter positions of the text by the process of word recognition (Bouma 1980). In this process, letter recognition and word contour recognition both contribute (Bouwhuis 1979); this is the reason for the greater legibility of text in lower case than in upper case: the ascenders and descenders of lower case letters provide a characteristic contour for many words. The legibility of text is defined here, following for instance Tinker (1964) and Klare (1969), as the effect of all relevant text properties, such as type face and colour, on the visual processes involved in reading. In contrast, the readability of a text is defined here as the effect of the style of writing, such as terseness and vocabulary used, on the cognitive processes involved in understanding the text (Klare 1969). While reading, the distance between successive fixation points along a text line, typically 8 ± 4 letter positions (Roufs and Bouma 1980), depends on legibility parameters such as luminous contrast (Leermakers and Boschman 1984), but also on text properties determining readability, such as the amount of redundancy present in the text. A series of letters and numbers forming a code, for instance, has little or no redundancy: every single character has to be recognized, which leads to very small forward saccades. Backward saccades, i.e. from right to left, are also made. Their most frequent occurrence in reading is from the end of a text line to the beginning of the next one, but they also occur within a line, presumably if a preceding part of a line has not been seen or understood properly, in order to gain more information there. The saccade directed to the beginning of the next line may be slightly misdirected if the required angle between this saccade and the text lines is small, with the result that a wrong line may subsequently be read. Such small eye back-jump angles are necessary with long line lengths and/or short inter-line distances. According to an estimate by Bouma (1980), the minimum ratio between line distance $d$ and line length $l$ should be 1/30 or 0·033, corresponding to an eye movement back-jump angle of 2°. Line distance is defined here as the distance between the lines connecting the bottoms of the short letters in two consecutive text lines. Short line distances may decrease legibility in yet another way, through visual interference. Letters or words in the vicinity of those being fixated during an eye-pause exert a masking effect, thus interfering with word recognition (Woodworth and Schlosberg 1954). Such masking may even cause one or more words to become ‘invisible’, that is, they might not be seen even when being searched for (Van Nes and Tromp 1979). The lines above or below that being read will interfere with parafoveal word recognition; the interference may be eliminated by increasing the
distance between the lines (Roufs and Bouma 1980). The extent of the visual reading field, up to 20 letter positions, warrants the assumption that most words are recognized at least twice: first in right parafoveal vision, i.e. at the right of the foveal area around the fixation point; second, during the next fixation pause, in foveal vision. However, subjectively each word is only seen once during reading. This may be due to the fact that parafoveal recognition is slow compared to that in the fovea (Schiepers 1974): by the time the first, parafoveal word recognition is finished, the second, foveal one is also completed, so the two recognition processes may actually cooperate (Bouma 1980).

3. Spatial effects

3.1. Line length and spacing

The text-carrying capacity of VDT screens is often rather limited: a videotex ‘page’, for instance, contains at most 24 lines of 40 characters each, i.e. 960 letters or around 150 words in all. Reading on from one videotex page to the next is usually more complicated than turning real pages of paper, which makes it difficult for the videotex reader to integrate the information from two or more successive pages. These two reasons may induce the editor of such pages to fill all available lines completely with characters. However, the minimal spacing of lines on VDT screens is usually rather small, leading to inter-line interference effects and, in combination with the relatively long text lines, to small eye back-jump angles.

For example, consecutive videotex lines of 40 characters mean a $d/l$ value of 0.035, very close to the minimum value recommended: 0.033. Thus, a text such as that in figure 1 has a marginal legibility as far as the control of eye movements is concerned. Another potential problem resulting from a small line spacing as in figure 1, in relation to the relatively large word spacing in videotex, about 1.4 times the character width, is that the integrity of the text lines is somewhat affected because the inter-word spaces, especially when preceded by a comma or period, tend to join to more or less vertical ‘rivers’ of space between the seemingly scattered words of the text. This could make it more difficult for the eyes to follow the lines.

![Figure 1. Full videotex page with a ratio between interline distance $d$ and line length $l$ of 0.034. The text is part of a humorous story.](image-url)
When the inter-line distance is increased, for example doubled by only using every other available text-line, \(d/l\) becomes 0.068, giving a higher legibility, as demonstrated by figure 2. An alternative way to increase \(d/l\) and, consequently, legibility is to decrease line length \(l\), for example to half its original value, so that \(d/l\) again equals 0.068. This results in lines of less than 20 letter positions, shown in figure 3, so typically three eye fixations suffice to read these lines. A smaller reduction of the line length, say by 20 per cent as found on some pages used by the German teletext service, 'Videotext', should increase legibility considerably and, subjectively, it indeed seems to do so. Used sparingly, this technique also makes the pages concerned look unusual and therefore interesting, especially when a page header with the full page-width is used.

Figure 2. The same text as in figure 1 with a doubled interline distance leading to a ratio \(d/l = 0.068\).

Figure 3. The same text as in figure 1 with a halved line length, leading to a ratio \(d/l = 0.068\).
Of course, the layouts of figures 2 and 3 have the effect of halving the text-carrying capacity of the screen, but this can in principle be overcome by having two columns on the screen as in figure 4. Such a text layout in columns is commonly used in newspapers to get acceptable d/l values; for example 0.061 was measured from a typical Dutch daily newspaper. However, such newspaper columns typically have lines of 32–34 spaces, compared to the 18–19 spaces of the columns in figure 4. Therefore it will be difficult to obtain satisfactory line-fillings with two-column videotex, as can be observed in figures 3 and 4. Newspapers frequently have a thin vertical separation line between columns, a technique which has been tried out on videotex. However, the available graphics only allow rather heavy lines which are so conspicuous that they may hinder rather than help the reading of the columns. Such a layout, i.e. that of figure 4 with an added vertical line between the columns, was compared with the conventional layout of figure 1 by a panel of 155 teletext viewers in the Netherlands in the autumn of 1980. They were asked by telephone which layout they preferred for reading comfort: 34 per cent preferred the two-column layout—which they had never seen on TV screens before—61 per cent the conventional one, and 5 per cent had no preference. Since respondents in interviews of this kind are known to prefer what they already know well, the result is an indication that a two-column layout may be worth further investigation. Probably the vertical separation bar should be left out, for one reason because research with printed text has shown that the legibility of a two-column text is not improved by separating lines (Tinker 1964).

3.2. Spatial grouping of text parts

With text printed on paper, subjects judged a page with a lot of open space between the text as being 'easier' and 'more interesting' to read than pages wholly filled with text (Smith and McCombs 1971). This judgment may be the subjective expression of the objective decrease of legibility through small eye back-jump angles and masking which accompanies densely packed text, as described in section 3.1. For VDTs with their often intrinsically restricted legibility due to unsharpness of the characters, unsteadiness of

![Welverdiende rust](image)

Figure 4. The text of figure 1 is redistributed here over two columns: a better legibility is obtained with the same text-carrying capacity of the screen.
the text etc., the insertion of some space on a page is probably even more important as a means of inducing someone to read it; see figure 5 against figure 6. The latter figure shows the spatial grouping of text in paragraphs which can be supposed by the reader to reflect several informational entities. The eyes may easily skim over such a text, guided by the empty lines to new subject-matter.

3.3. Overall page layout

Figure 7 shows the main index of the Dutch teletext service in the first months of 1981; it serves to illustrate two layout aspects:

Utilization of display space on the page as a whole.

This page shows little empty space, which is regrettable as explained in the previous section, although it may be unavoidable on an index page. However, in this case the logo and the rather uninformative line HOOFDINHOUD (MAIN INDEX) take up 6 of the available 24 lines of text, which seems a bit wasteful.

Tabulation. The page has two different systems of two columns plus three pieces of text which run over the whole width: this makes it difficult to survey the page. The unclarity is increased by the situation of the page numbers, which are placed at the left of the page titles in the upper columns, and at the right in the lower columns. Especially when two separate columns of information are present as in figure 7, placing page numbers to the left of the items they refer to, as in the upper system, probably is better than placing them to the right, as in the lower system. The line with the page numbers 101/102, and that with the numbers 300/500 show that the numbers in the first column then are often closer to the non-related items in the second column than to the proper first-column items, which may be confusing. Second, the distance between item and related page number is smallest as well as constant when the numbers are ranged left, which means that there is less chance for making mistakes in reading across.

Figure 5. A densely packed text, about 'General information on Manchester', does not appear inviting to read.
3.4. **Order of items in tables**

The order of items in tables, e.g. in indices, should follow some principle which can be recognized and easily used by the reader. This is not the case in figure 7: the list of systematic sub-indices in white letters, and the list of popular pages in cyan, are ordered neither alphabetically nor according to increasing page numbers. The latter ordering principle has been applied in the page depicted in figure 8: it makes the left column look regular but is not really helpful in a search for a particular item, which can be found only by reading the whole words behind the numbers as against, for instance, scanning the first letters of these texts in an alphabetical list. The list of figure 8 is certainly not alphabetical: ‘Consumer info’ is at the top, whereas ‘Consumer on radio’ and ‘Consumer on television’ is at the bottom.

4. **Colour effects**

4.1. **General aspects of the legibility of coloured text**

4.1.1. **Recognition**

The recognition of a coloured text, either on a coloured or on a ‘black’ background, depends mainly on the luminous contrast between letters and background. Colour contrast plays a very subordinate part (Bouma 1980, Bruce and Foster 1982). This is of importance for the legibility of coloured texts, also in systems such as videotex, i.e. systems that do not compensate for the differences in luminous efficiency between the red, blue and green phosphors, which means that the seven available colours are unequal in brightness. Their luminosity and brightness order is, from high to low, white, yellow, cyan, green, magenta, red, blue.

With a dark or ‘black’ background, the first four colours are best suited for rendering text; red and especially blue are inappropriate because their luminance is too low. But on a bright background i.e. white, yellow or cyan, the letter colour should rather be dark, e.g. blue, red or magenta, in order to have enough luminance contrast. For people with defective colour vision, it is important to provide sufficient luminance contrast when colours are used between which they find it hard to distinguish, such as red letters on a green background. Readers with anomalous colour vision may not see those colours as different, but still are able to read because of the luminance difference between the text and background.

It should be realized that on displays with a 50 or 60 Hz refresh rate, as employed in videotex systems, high-luminance backgrounds show annoying flicker effects, especially when large areas are involved.

From the above it can also be concluded that, for a monochrome display, the colour of its phosphor has little if any effect on legibility as long as the luminances produced by the phosphors considered are equal (e.g. Radl 1980).

4.1.2. **Sharpness**

Present colour cathode-ray tubes generate three primary colours: red, green and blue. All other colours are obtained by mixing the primaries; in videotex this applies to white, yellow, cyan and magenta. If the cathode-ray tube is not adjusted properly, letters in colour mixtures will show margins with one of the component colours, especially at the display edges: this may give an impression of unsharpness.
Algemene informatie Manchester

Manchester is een van de belangrijkste industriesteden en handelscentra van Groot Brittannie. Belangrijk handelsproduct is katoen.

Manchester dankt een deel van haar bekendheid aan twee voetbalclubs: 'Manchester United' en 'Manchester City'.

En aan de gastvrijheid van de bewoners.

In het centrum van Manchester vindt U een diversiteit aan winkels en uitgaansmogelijkheden.

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Figure 6.

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Figure 7.

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Figure 8.

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Figure 9.
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4.1.3. Chromatic aberration

Magenta is composed of the primaries red and blue, the colours with the largest wavelength difference in the visual spectrum. Due to the chromatic aberration of the eye, these two colours cannot be focused simultaneously, i.e. at the same eye-lens accommodation, which causes a certain unsharpness of magenta letters on the retina. This phenomenon has been reported to be experienced more especially by some wearers of spectacles, due to the additional chromatic aberration of their particular spectacle glasses.

4.1.4. Colour stereoscopy and 'fluttering hearts'

Red or blue letters on or near to a blue or red background, respectively, give a subjective impression of depth, an effect called colour stereoscopy. This depth effect may be used on displays, as in printed advertisements, to attract attention. The display editor should not, however, cause the effect unknowingly out of ignorance, because it may be a hindrance to normal reading. The latter also applies to the 'fluttering hearts phenomenon': combinations of colours from the blue or green and the red part of the
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4.2. Specific relations between reading processes and colour

4.2.1. Synopsis

Apart from the general aspects mentioned, the application of certain colours on displays may have several direct or indirect effects on reading, either wanted or unforeseen by the editor of the display text:

- association of parts of the text with the same colour by perceptual grouping;
- accentuation of small parts of the text with a colour differing from that of the surrounding text by their conspicuity;
- categorization of parts of the text, for example according to semantic importance, by coding of those parts by their colours;
- facilitation or inhibition of reading through the generated impression of orderliness or chaos, respectively, by the amount of colours on the display;
- generation of aesthetically pleasing or displeasing effects by the applied combination of colours.

These effects will now be dealt with in more detail and illustrated with examples.

4.2.2. Association by colour grouping

People have a strong tendency to interpret identically coloured parts of a text and/or figure as belonging together. This association mechanism which groups texts and/or figures only operates well, however, when not more than three or four colours are present on a page (Reynolds 1979). The grouping effect is ascribed to the formation of a ‘Gestalt’ by parts of a text of the same colour; however, such a Gestalt is thought to break down when too many different colours are present (Cahill and Carter 1976).

Figure 7 shows a probably unintentional colour grouping effect which is supported by a spatial one. Both effects wrongly suggest a relation between information of television subtitles (added via teletext for the deaf), p. 523, and information on regional radio broadcasts, pp. 526–531. An intentional colour grouping effect appears in the youth theatre list of figure 9: the names of the theatres and the times of performance are all displayed in green; the names of the plays and performers are in cyan; the names of the cities where the theatres are located are in yellow. Spatial grouping is applied as well in figure 9, where the information for Amsterdam, The Hague etc. is separated by means of empty lines. However, the colour and spatial grouping mechanisms can also be seen to interact here in a negative way: the spatial grouping of information per city is broken up by the use of three text colours in every set of two or three lines.

4.2.3. Accentuation by colour conspicuity

If a part of a text or figure has a colour which is different from the surround, this part will have an objectively measurable increased conspicuity (Engel 1980), and the degree of its conspicuousness will depend among other things on the colour combination. This means that the differently coloured part will involuntarily attract fixation of the eye when it scans the page. Colour differences therefore can deliberately be used as efficient search aids, e.g. in a list such as that in figure 9, the names of cities where certain youth plays are staged are yellow, and thus may easily be found in a text which is otherwise
green and cyan. Anticipating section 5, it may be remarked here that, apart from the heading, these city names are the only words in capitals on the page, which gives an extra accentuation.

Summarizing: a part of a text may be rapidly found by giving it a specific colour, provided the reader knows which colour to look for.

A text may also be accentuated by displaying it on a conspicuously coloured background; if the background is normally black, any bright background will be conspicuous. The red background block in figure 7 is only moderately conspicuous due to its low luminance, although it is the only red on this display page. The heading may actually attract equal or even more attention due to its relatively bright background and graphical lettering; in general, the 'teletext' logo will thus distract the reader from searching the main index.

In figure 8, showing the systematic index 'Consument' (Consumer), the page numbers of the other systematic sub-indices are also mentioned. It is debatable whether the valuable space on a sub-index page should be used at all for this purpose. At all events, the accentuation, possibly unintended, of the other sub-indices by giving them a conspicuous background seems to be unjustified.

4.2.4. Categorization by colour coding

The colour of a text may be used to code the text, i.e. to attach a specific meaning to it which is not necessarily conveyed by its content. One example of such coding is that caused by the transfer of a colour's subjective importance to the words that appear in this colour; words printed in red therefore are generally assumed to be important. This does not, however, apply to words displayed in red on a dark background, as usually obtains in videotex, because the luminance of such words is low in comparison to that of words in other colours. Assuming with Reynolds (1979) that the brightest colours are perceived as most dominant, white parts of a text would be regarded as the most important, followed by yellow, cyan and green ones, in descending order of importance. This dominance scale could in principle be used for structuring and accentuating a text, but research on this subject is necessary. The use of white letters for the sub-indices ('rubrieksoverzichten') in the teletext main index of figure 7 might thus be called a good choice—a red background was used for these sub-indices with the same aim—whereas the choice of cyan for the most popular items, such as the latest news or the weather forecast, would appear to be sub-optimal in terms of a dominance scale.

To a certain extent, colour coding of semantic importance may not need to be learned specifically for reading text displays but has already been acquired from previous experience. This does not apply to a second form of colour coding, where certain agreements are made beforehand as to the meaning of specific colours. For example, in the subindex 'Consument' (Consumer) in figure 8, the colour cyan (here called 'blue') is used to indicate that the items on pp. 207 and 221 are temporarily not being broadcast—as is stated, in Dutch, on the bottom line. In the alphabetical index, partly shown in figure 10, a similar agreement is indicated on the bottom lines: pages with a cyan text are only broadcast if any information is available. So the reader is trained that 'cyan' means 'absent'. However, on the most important teletext page, the main index of figure 7, cyan is used for indicating the most popular pages which are always broadcast! It is obvious that colour coding can only be fully effective when it is consistent through the whole of an information system, computer program or whatever system it is used in.
4.2.5. Facilitation or inhibition of reading by order or chaos

If a display shows text or graphics with not too many different colours, visual search processes are aided and subsequent reading is not impaired by over-conspicuous parts of the display. If, on the other hand, a multitude of colours is scattered over the whole display area and structure is lacking, the reader is bewildered by this colour chaos even before he starts reading and distracted while he is doing so. Colour and spatial effects cannot really be separated here since possibly intrusive colours necessarily have to appear at a particular display position, either as text or as its background. Of the figures already described, figure 7 shows four text colours as well as two background colours apart from 'black', which unnecessarily decreases the legibility of this page.

Figure 8 also shows four text colours, plus one extra background colour, which is wrongly used here to accentuate what is in fact secondary information on this page, viz. the page numbers of the other sub-indices from the data base. The page numbers of the alphabetic index, however, are directly under the heading, in green letters without background. It is justifiable to use another colour than yellow and cyan for this secondary information, but the use of a new colour, at another place, does increase visual chaos on this page.

In figure 10 it can be seen that the alternation of two text colours is enough to create unrest; this is made worse by the presence of two areas with different background colours. On the real display, the background of the heading was in addition flickering because of its high luminance. One colour instead of two for the 'graphic' letters of the heading would seem to be sufficient. There is also some red present in figure 10: it is apparently used to mark the start of a section with a new first letter—in a way that would be effective on paper, but is not on the dark background of videotex (which is approximated reasonably well by the colour photograph). Because of the colour coding applied to indicate that pp. 425 and 218 are among those that may or may not be broadcast, there seems on the face of it to be a rule that the first item with a new first letter is always displayed in cyan.

4.2.6. Aesthetic colour effects

The previous section described objective, measurable effects of colour combinations on text legibility. Subjective effects of single or multiple display colours on the viewer, such as whether he considers those colours to be aesthetically pleasing or not, probably do not directly influence his performance, yet may affect his appreciation of the displayed text as a whole; this appreciation might be measured by means of interview techniques. For example, monochrome texts in yellow are generally considered 'warm', whereas texts in cyan are considered 'cool'; it may depend on the taste of the viewer which one is preferred.

As for multicolour displays, again colour and spatial effects cannot really be separated. The author hesitates to comment upon the aesthetic aspects of the figures in this article, 'taste' being such a personal matter. Just one remark, therefore, on figure 8: the combination of the big block of magenta carrying a dark blue text, with the mainly yellow, i.e. light text on the rest of the page, may be suboptimal in an aesthetic sense—apart from the more objective disadvantage mentioned in section 4.2.3.

5. Typographic effects

5.1. Possibilities for typographic coding on displays

Typographic coding is defined here as the attachment of a specific meaning to a part of a text by printing or displaying it in a way which is different from the rest of the text.
Typographic coding in print is mainly used for two purposes: to indicate headings and to accentuate; the accentuation can relate to single words, phrases or whole paragraphs.

On electronic displays typographic means used to indicate headings, i.e. words or parts of sentences at the top of a page or paragraph, are also available, for instance the use of capitals, double-height characters or graphics characters. For accentuation, however, most present-day displays of low or medium resolution offer little more to differentiate between accented and other text than a choice between upper and lower case; in videotex characters can also be displayed in normal or double height (but in one single width). Present videotex characters are based on a $6 \times 10$ dot matrix which excludes a differentiation between normal and bold character shapes. A $12 \times 10$ dot matrix will be introduced shortly which will allow this differentiation and thus increase the scope for typographic coding. Another possibility for coding, consisting in variations of the spacing between the letters of words, does exist on displays to a certain extent, in the form of normal spacing versus the insertion of whole letter spaces between consecutive letters. Such insertion is not to be recommended, however, since the normal interletter spacing is already variable because of the constant matrix width available for letter plus adjacent space. This leads to comparatively wide spacing for narrow letters such as i, j, l and t, as can be observed in all figures in this paper.

5.2. Capitals

The use of capitals in running text or tables should in general be discouraged for two reasons:

- The contours of capitalized words are less characteristic and this impairs word recognition (Bouwhuis 1979), even in headlines (Poulton 1967).
- The space between two textlines in capitals is relatively small. Vertical masking is therefore increased and, especially in tables, the small space may lead to text blocks which appear dense and uninviting to read, as can be seen in the right half of figure 8 and the left half of figure 13.

On the other hand, figure 8 also shows that capitals may be used advantageously for typographic coding, in this case to distinguish two parts of the page, on the one side references to information pages and references to index pages on the other. Capitals are also useful for headlines or for indicating new paragraphs, such as the city names in figure 9.

Capitals may be confused with numerals when legibility conditions are poor, as they are at the large viewing distances with teletext. In order to minimize the probability of such confusion in a set of optimally discriminative characters for use in teletext (Van Nes 1983, 1984), the numerals were made bold with respect to the lower and upper case characters. In this way the notoriously difficult discrimination between the numeral 0 and the capital O is easy, as can be observed in the lower left corner of figure 10, featuring the newly developed $12 \times 10$ dot-matrix characters. However, this works only if the code for the digit 0 is in fact broadcast—which is not always the case, because some editors of teletext do not make the distinction, or dislike the diamond-shaped 0 now in use and transmit the code for 'capital O' instead (this may for instance be seen in figure 8, which features the $6 \times 10$ dot-matrix characters used at present: all zeros but the, apparently forgotten, middle digit in the number 206 have been replaced here by the capital O. Especially if some zeros are replaced by the capital O and some
are left alone an odd mixture results, as may be observed in figure 10 (‘202’, ‘406 t/m 408’ and ‘Top-10’).

Figures 7, 9, 11 and 12 of this article show the present $6 \times 10$ matrix characters, whereas figures 1–6, 8, 10, and 13 have the new $12 \times 10$ matrix characters, which have been called ‘IPO-Normal’ (Van Nes 1983, 1984).

5.3. Double-height characters

The possibility to display one half of a teletext page at double height with double-height characters, was originally introduced for readers with somewhat reduced visual acuity—indeed, many may be expected to encounter reading problems at the prevailing teletext viewing distance. An additional use of double-height characters is for emphasis, for instance in the heading or title of a page: titles in a mixture of upper and lower case double-height letters can be seen in figures 1–6 and a heading in double-height capitals is shown in figure 13.

5.4. Graphic character fonts

For headings, ‘graphic’ letterfonts may be constructed out of the elementary units for making graphics. Because of the considerable size of these units, such letters are rather coarse and large—the headings therefore occupy two lines of text or more. In comparison, a heading in double-height characters also occupies two lines of text, but the letters in headings like those of figures 9 and 10 are 30 per cent higher and certainly more conspicuous—although in this case probably less legible due to the unusual character configurations. A graphic alphabet generally shows a mixture of upper and lower case approximations because diagonal and rounded letter strokes cannot be made satisfactorily. This is clearly demonstrated by the graphics V in the heading of figure 10, which could easily be mistaken for a U. Moreover, the graphics S in this heading by itself is indistinguishable from the numeral 5.

Besides the spatial and colour grouping mechanisms already discussed, a similar typographic grouping mechanism also appears to exist: one does not easily perceive the words ‘van de rubriek’ in the heading of figure 8 as connected with the graphics words—although together they constitute a grammatical sentence in Dutch, ‘Synopsis of the category Consumer’. It helps that both fonts have the same colour, but not enough because there is more yellow text present on the same page (on another, similar sub-index page, broadcast in the same period, the first and last words of the heading ‘OVERZICHT VAN DE OMROEPRUBRIEK’ were displayed in cyan graphics font whereas VAN DE was displayed in yellow normal capitals). Figure 9 on the other hand shows that a common background, in this case white, clearly groups the parts of the text in graphics with those in normal font, which is facilitated by both fonts being equally coloured.

6. Design and evaluation of some alternative index pages

6.1. Combined effects of space, colour and typography

The separate effects of space, colour and typography on display legibility have been described in the foregoing, illustrated with practical examples. The comments made are based partly on results and inferences from research, partly on common sense.

It is legitimate to ask for objective or subjective proof of the validity of these comments, obtained for example from measurements of parameters which characterize
the visual reading process, such as reading rate, eye movements and fixation durations, or by asking subjects for their opinion on particular display layouts. Objective trials indeed need to be done, but in the absence of an immediate opportunity for that, we welcomed the suggestion from the ‘Viewing and Listening Inquiry’ Department of the Dutch Broadcasting Foundation to include a number of questions in their public opinion polls on two versions of a teletext page with the same contents: one as it was currently being broadcast and one with a design based on the principles described in the previous sections.

The results of an inquiry of this type must be judged with caution: for one reason because people have a tendency to prefer the well known, in this case conventional layouts. Therefore, the opinion poll results are presented here as secondary information; the main aim of the following two examples is to show the combined effects of changes in layout, colour and typography on index pages.

6.2. Main teletext index

Figure 11 shows the main index page of the Dutch teletext as broadcast in the 11th trial period, in November 1980. In that period the colour cyan was not yet used to indicate that the item concerned may not be broadcast, as described in section 4.2.4. The logo occupies 5 of the 24 lines of text, which seems wasteful; also it appears to be too conspicuous. However, its presence in the test page, too, was regarded as essential by the teletext management. In figure 12 a number of changes have been made:

1. The page is structured in two columns, as against a mixture of one and two columns in figure 11.
2. The reference to the alphabetical index is put above the systematic sub-indices, instead of at the third line from below. Moreover, it is split up into four parts so one can immediately choose the correct page number, say for letter H, instead of having to estimate this number.
3. The titles of index pages as well as information pages are all yellow; apart from the logo there are no background colours. Only three categories are indicated using cyan: the alphabetical and systematic sub-indices, and frequently requested information pages. It might perhaps have been better to use yellow for these indications too, so that there would have been only one text colour and the possibility of grouping the category indications would have been avoided.
4. The frequently requested pages (‘veel gevraagd’) are now ordered alphabetically, together with two which contain important information about sub-titles for the deaf (p. 199) and the teletext medium as such (p. 517). There is no more reference to pp. 103 and 217, because frequently there was no information on these topics in November 1980.
5. The first text line of figure 11 is omitted because it is unimportant: ‘Main index’ is obvious from the logo; ‘11th trial period’ and ‘100 pages’ are hardly relevant at a main index. The same applies to the last line in figure 11: ‘All page numbers are represented in indices’.

In the telephone inquiry which followed, 138 teletext viewers were asked about their preference for either the main index as in figure 11 or as in figure 12, with respect to ‘most pleasant and tranquil reading while searching’. The well known existing layout of figure 11 was preferred by 36 per cent, whereas the new layout of figure 12 was preferred by 58 per cent of the viewers; 6 per cent had no preference.
6.3. *Alphabetical teletext index*

Figure 13 shows, at the left, the first section of the alphabetical index of teletext broadcast in The Netherlands in November 1980, and an alternative design at the right, with the following changes:

1. The demarcations of items with the same first letter are empty lines apart from a yellow capital indicating the first letter of the next group of items. This demarcation is more effective than the colour change of the first item with a new first letter, as applied in the left column; the right column is therefore easier to search through, which will outweigh the fact that it counts four items less than the left column.

2. Apart from the first letters and the acronyms ANWB and AVRO, the right column is in lower case letters as against the majority of the left column text being in upper case. The items with B, C and D are, in particular, a good example of a block of capitals with what has been called 'a solid and impenetrable appearance' (Reynolds 1979), described in section 5.2.

3. The sub-items 'concept', 'sport' and 'theater' of the item 'Agenda' are denoted by a dash before the word and have been moved towards the relevant page numbers with respect to the left column, where they were put in parentheses, in order to indicate more clearly that all three cases concern agendas.

4. The background of the heading is blue instead of white, in order to avoid the flicker of this white background on the real display.

In a telephone inquiry similar to that described in section 6.2, 157 teletext viewers from the same panel were interviewed about the effect of the four changes on either the left or the right column being 'most pleasant and tranquil to read' while searching for a specific item. The following results were obtained:

1. (as to the chosen demarcation) 51 per cent preferred the left, 47 per cent the right column and 2 per cent had no preference.

2. (as to upper versus lower case) 50 per cent preferred the left, 41 per cent the right column and 9 per cent had no preference.

3. (as to the sub-item indication) 22 per cent preferred the left, 75 per cent the right column and 3 per cent had no preference.

4. (as to the colour of the heading) 59 per cent thought the white heading attracted attention most, 39 per cent felt this was so for the blue one and 2 per cent said there was no difference.

When comparing the complete columns, 42 per cent thought the left one looked 'most pleasant and tranquil', 55 per cent thought so of the right column and 3 per cent felt there was no difference.

7. **Conclusions**

7.1. *Research topics*

In order to obtain optimal legibility of text and graphics on VDTs, knowledge of the visual reading process is required. Most of this knowledge is available in the literature but research on several aspects of this process would yield very useful additional knowledge. For example, what is the relative contribution of colour contrast to word recognition, besides luminance contrast? It will be small, but not negligible for certain
colour combinations. Probably even more important is the development of a quantitative measure of the conspicuity of differently coloured text parts, and the related degree of attention capture, at first sight or continuously. In general, data on the effect of layout and colour on the legibility of information pages and ease of search in index pages could provide a more quantitative foundation for the guidelines given on these topics here.

7.2. Practical guidelines

7.2.1. Usage of space

(1) A page filled with text is hard to read. Its legibility can only be substantially improved by the insertion of empty lines, not by using different text colours. Division of a text into paragraphs of three to five lines, with empty lines separating the paragraphs, improves legibility without too great a loss in text quantity.

(2) The emptier a page, the easier it is to search it. This applies especially to index pages, which should therefore contain only essential information. Their layout should be orderly and consistent; that is, the text should always be laid out in the same one or two columns, which preferably should be divided into groups of not more than five lines, by regular insertion of empty lines.

7.2.2. Usage of colour

(1) Dark text on a bright background is more legible than the reverse, provided that the display refresh rate is high enough, i.e. 70 Hz or more (Van Nes 1984). For television-type VDTs with a 50 or 60 Hz refresh rate, this means that sizeable quantities of text have to be displayed on a dark background, in white, yellow, cyan or green—or a comparable colour range if other colours than the seven provided in videotex systems are used. Text colours such as videotex-magenta, -red and -blue are not luminous enough for a dark background and therefore may only be applied on a bright one—which will, however, flicker intolerably at a refresh rate of 50 Hz unless the area it occupies is relatively small.

(2) Not more than three colours should be used on one page for sizeable quantities of text. Parts of a text with the same colour will be regarded as belonging together; this effect can be utilized, but may also cause confusion if there is no relation between the texts of the same colour.

(3) A part of a text or figure with a colour different from its surround is conspicuous and so attracts attention. This effect may be helpful to a reader when searching for certain information on a page, provided he knows which colour to look for.

(4) If colour coding is used in an information system, it should be used consistently, i.e. the coupling between colour and meaning should be the same on every page.

7.2.3. Usage of typography

(1) The legibility of text with letters in mixed case, i.e. with capitals only used for indicating the first letter of a sentence, a name etc., is higher than in upper case only. The use of capitals for all letters of a word or sentence should therefore be avoided except in headlines or, possibly, to indicate a difference of category.
(2) Graphics character fonts are attention-catching because of their size and unusual shape, but are less legible than normal fonts. If graphics characters are used their acceptability and discriminability should preferably be investigated (Bouma and Leopold 1969).

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