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by Konstantinos S. Papadopoulos and Dimitrios B. Goudiras

The use and applications of new technologies in the education of the visually impaired have made substantial strides forward in recent years. New technology allows the visually impaired to enjoy better access to information, to read for themselves and, by extension, to improve their learning literacy. Nevertheless, despite the advances made in assistant technology, a number of problems have arisen in relation to the limited experience of both users and teachers in handling that technology. Teachers also need to take into account the diversity of characteristics of impaired vision in the visually-impaired population, taking steps to make the educational material available with effective colour contrast and in legible text. The aforesaid problems are even more severe for teachers in the regular classroom. This article describes the effective colour contrast and legible text required by visually-impaired students and presents a new tool, not intended merely to provide another form of computer access for the partially sighted, but to offer a means of education in the regular classroom.

Introduction

Today, technology has become part of general education and special education classrooms. Thus educators, parents, experts, and legislators have become advocates for ensuring equal access to technology for students with various disabilities (Rex et al., 1994). However, little qualitative research has been done to document the importance of computers and computer-related assistant technology in visually-impaired individuals. There have been some efforts from relevant studies to document the impact of computer-related assistant technology on classroom performance, general literacy, job placement and maintenance, and overall quality of life. Other research has begun to document some of the barriers to access. However, that information does not cover how these barriers are perceived. In addition, the ways in which these barriers can create even greater inequality for people without access to computers in an increasingly digital world does not get examined (Gerber, 2003).

Over the last ten years a large number of people with impaired vision have been enabled to enjoy access to computers. The screen reader and screen magnifier – the method of choice for the majority of those with visual impairment – is a necessary tool for computer use. In the Corn and Wall (2002) research, an overall 58.5 per cent of people with low vision daily used the screen magnification software.

How important assistive technology is for visually-impaired people has been documented in the Gerber (2003) research, where its importance is emphasized in various fields, like jobs, access to information and social/community networks. Computers provide access to information and allow individuals to read. Their use is integral to learning outcomes and literacy. It is well known how important it is for a visually-impaired student to be able to read, which in turn improves individuals' writing skills. However, it carries an added weight for this population, since people who do not have access to print find it more difficult to attain literacy skills. According to Gerber (2003), computers balance some of the effects of visual impairment and give visually-impaired individuals equal opportunity to achieve in productive ways with sighted individuals. She also believes that the use of computers should be an integral part of the so-called core curriculum for children and a required part of all vision rehabilitation for adults.

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Using electronic magnification for enlarging printed material has been found to increase the reading rates of individuals who are visually impaired (Pattillo et al., 2004). Increasing the reading speeds of children with low vision has been a concern of educators for many years. Children with low vision have academic difficulties if their reading speeds are not competitive with those of their sighted classmates (Corn et al., 2002). At the same time, current estimates predict that people with visual impairments are much less likely to use computers than are sighted people (Gerber, 2003).

Another important matter is the experience of visually-impaired students who are computer users. How much further users' experience can progress has been predominantly examined by mainstream computer professionals, who are only now beginning to deal with the complex needs of users with disabilities. Only a few computer professionals specialize in the area of visually-impaired computer users (Gerber, 2003).

Teachers' technology training

The need for professional training of vision support teachers in the use of new technologies and their ability to teach and support students in the use of computers is a significant issue. One major challenge for educators, according to Kelley (1998), is that individuals may not be fully aware of innovations. Itinerant or visiting teachers must be trained to the point of proficiency in new technologies in order to promote their use by students with vision impairments (Kelley, 1998).

The most widely used word processing software, Microsoft Word, is used by a significant number of blind and partially-sighted people around the world. In the Corn and Wall (2002) research it is reported that 69.7 per cent of people with low vision use this software daily.

Microsoft Word is compatible with the various screen reader software programs. Professionals are taught to use it in almost all computer training programs for the visually-impaired, with the result that the software involved has established itself as a vital tool in education and communication for visually-impaired people. Its widespread use by sighted people is of great help in communication between the sighted and the visually impaired, and in its use as an educational tool by teachers.

In addition, teachers of visually-impaired students feel more familiar with general technology than with technology designed specifically for students with visual impairments. The majority (92.1%) of the 410 teachers of visually-impaired students who participated in the Corn and Wall (2002) research felt well capable of dealing with word processing programs; 81.7 per cent could use email; and 70.1 per cent could access the internet for personal use. However, only 50.6 per cent of the respondents said they had a material knowledge of software such as screen readers used by students with visual impairments.

In the same research, the barrier, reported by 67 per cent of the respondents, was the need for further development of teachers' skills. One other barrier, reported by more than 40 per cent of the respondents, was inaccessible content and insufficient time with students. In response to the question about solutions to barriers, the need for additional technology training for teachers was the predominant barrier, as well as the predominant solution (38.9% of responses). More funding for equipment, software, and upgrades was listed by 37.1 per cent of the respondents (Corn and Wall, 2002).

These findings show the necessity for teachers of visually-impaired students to learn more about access technology, but also raise some questions. We have already noted that teachers of the visually impaired have certain special needs – needs identified in research into the teaching of visually-impaired students in a number of developed countries, including Canada and the USA. It is only reasonable to assume, then, that these needs are even more acute in the case of teachers working in the regular classroom. Our experience indicates that here in Greece there are very few teachers working in regular classrooms (non-specialists) who are familiar with the assistant technology for visually-impaired students, while only a tiny number of regular schools have the appropriate assistant technology infrastructure. Another factor causing significant problems for regular classroom teachers trying to help visually-impaired students is the teachers' own ignorance of the nature of visual impairment, of methods of teaching and assisting these students, and of presenting the educational material in the appropriate format (text size, contrast, etc.). In countries like Greece – where there is no support available for the regular classroom teacher from special teachers trained in the education of the visually impaired – the problem is even more serious.

It is well known that there is wide diversity of characteristics of impaired vision in the visually-impaired population. The providers of educational materials for the visually impaired must take this diversity into account, providing for multiple options in specific visual fields, e.g. the contrast between background and text, the size of characters, the weight of characters (bold, normal, etc.), the space between the lines of text, and the space between the characters. The selection of the appropriate settings for these fields is directly related to the speed of reading.

Effective colour contrast and legible text

Most visually-impaired individuals suffer from defects in their perception of colours, which reduce their ability to recognize basic colour combinations (Arditi, 1999b). The most common failing in colour recognition is the inability to recognize red and green (Vaughan et al., 1971). To reduce the likelihood of difficulty in reading caused by poor colour differentiation, we must avoid the coexistence of these two colours on the same working surface.

In recent years, the contrast dimension has received increased attention in studies of vision (Rubin and Legge, 1989). There are two aspects of contrast which are important to low-vision readers: contrast magnitude and contrast polarity (the distinction between light text on a dark background and the reverse) (Rubin and Legge, 1989). In designing aids for the visually impaired we need to establish as a rule that both the text and, generally, the working surface must present the maximum contrast magnitude.

To create effective colour contrast for each user, it is important to be aware of the three most important perceptual characteristics of colours: hue, lightness and saturation. Hue is the term for the pure spectrum colours commonly referred to by the ‘colour names’ – red, orange, yellow, blue, green violet – which appear in the hue circle or rainbow. It is a characteristic of colour that it denotes a colour in relation to red, yellow, blue, etc. Hue is what allows us to distinguish between basic colours. Those with perfect vision perceive the hues following a series based on the similarity between them. In most cases where there is a problem in colour perception, the individual’s ability to distinguish colours on the basis of hue is diminished.

Lightness corresponds to the degree to which light is reflected off a surface in relation to neighbouring surfaces. Like hue, it is a perceptual characteristic which cannot be calculated only by physical measurement. It is the most important of the characteristics of colours, making the contrast between them more effective. In many cases of defective colour recognition, especially those resulting from eye disease or advanced age, the ability to distinguish colours on the basis of lightness declines.

Saturation (colour purity) is a feature of the intensity of colour which differentiates its perception from a white, black or grey of equal lightness. Saturation measures the vibrancy or purity of a colour. A pure colour has no grey mixed in it. Blue-pink is an example of a colour which has no chromatic purity, being similar to grey. A deep blue of equal lightness with blue-pink has more chromatic purity. Both congenital and acquired defects in perceiving colours are associated with the difficulties in recognizing colours from their saturation. This is especially the case with colours of specific hues and depends on the specific type of defective colour perception (Arditi, 1999b).

These three characteristics of colours can be represented geometrically in the form of two cones with a shared circular base, as in Figure 1. The vertical change in colour in this geometrical figure is due to the changing lightness (luminance). The vertical dimension of the figure represents the lightness of colours, starting from the bottom of the figure (black – minimum lightness) and rising to the top (white – maximum lightness).

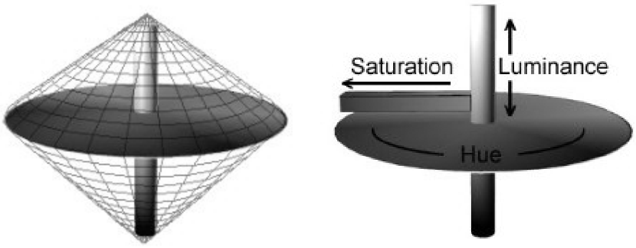

Figure 1: Geometrical representation of the three characteristics of colours (Nebulus, 1999)

At whatever point we choose to make a horizontal incision and represent the cross-section we have uncovered, the result will be a circle consisting of the eight basic colours (Stamopoulos, 1999). It is important to emphasize that at whatever point we take the cross-section, the colours in the circle will be of the same lightness. If the cross-section is at the point where the two cones meet, i.e. along their shared base, the circle we shall see is also known as Newton’s Palette. Each of the eight colours has a different degree of hue. The fact that the shape of Newton's Palette is circular helps us to represent the hue in degrees. Thus, for example, the red colour has a hue of 0°, the yellow 90°, the green 180° and so on (see Figure 2). Finally, the saturation or chromatic purity of the colour is represented by the radius of the hue circle. In the centre the saturation is equal to zero, while at the circumference the maximum value is equal to one.

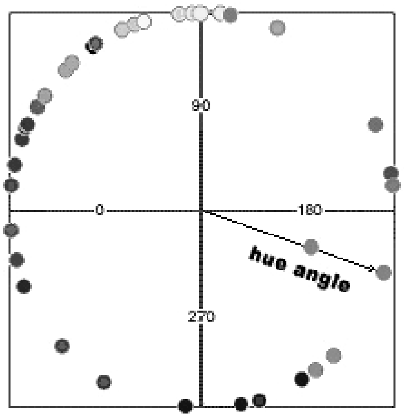

Figure 2: Degree of hue of the basic colours (handprint site: http://www.handprint.com/HP/WCL/color6.html, cited in Stamopoulos, 1999)

People with impaired vision usually have difficulty in distinguishing colours of the same hue. We must therefore avoid contrast of colours from neighbouring points on the hue circle, especially if the two colours are not strikingly contrasted in terms of lightness. The lightness discerned and perceived by a person with healthy vision is not the same as that perceived by those with defective colour perception. In general terms it can be assumed that the latter will make out less contrast in the colours. If the colours are 'lit up', the light colours becoming lighter and the dark colours darker, then the contrast is greater (Arditi, 1999b).

The differences in lightness between the content of the working surface (graphics, text) and the background must be emphasized, and use of colours of the same lightness must be avoided, even if they differ in saturation and in hue. In making our selection we must opt for darker colours with hues represented in the lower half of the hue circle (see Figure 3) instead of light colours from the upper half of the circle (or white). Also to be avoided is the contrast of light colours from the lower half of the circle and dark colours from the upper half (or black) (Arditi, 1999b). Fine and Peli (1995) examine the effects of character size and the effects of lightness using a monitor and a low-vision magnifier. They conclude that some reduced-vision readers may benefit more from increased lightness than from the use of larger characters.

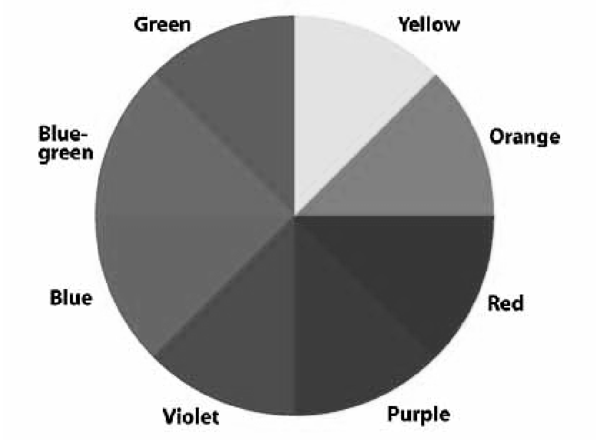

Figure 3: The circle of hues (Arditi, 1999b)

The effect of contrast polarity on normal reading has been widely studied. The major finding is that there is little difference in reading speed for white-on-black vs. black-on-white text over a wide range of character sizes, from 0.06 to 12 degrees (Legge et al., 1985a) or as a function of contrast magnitude (Legge et al., 1987). However, it has long been known in clinical practice that some low-vision observers read better with 'reverse contrast' text, that is, white letters on a black background (Rubin and Legge, 1989). Legge et al. (1985b) found that low-vision observers with cloudy ocular media read up to 50 per cent faster with reversed-contrast text. For many readers who are partially sighted, light letters (white or light yellow) on a dark (black) background are more readable than dark letters on a light background (Arditi, 1999a; Eperjesi et al., 1995; Gaster and Clark, 1995). Harrison found that coloured printing on white paper and black printing on coloured paper decrease legibility, even for normally-sighted people (Harrison, 1975, cited in Davies, 1989).

Very important factors in limiting reading speed for high contrast text are cloudiness of the ocular media and loss of central vision. The major effect of cloudy media is a reduction in retinal image contrast due to light scatter, so individuals with cloudy media act like normal readers of lower contrast text (Legge et al., 1985b). Individuals with central field loss must rely on peripheral vision in order to read. It is believed that peripheral vision is normal in some disorders that lead to central vision loss. Other disorders which can cause central vision loss, such as cone dystrophy and optic neuropathy, are known to affect peripheral vision as well (Rubin and Legge, 1989). The loss of peripheral vision reduces the number of letters simultaneously visible. According to Legge et al.

(1985a, b), at least four or five letters must be visible for optimal reading of scanned text. However, provided that the intact central field is large enough to accommodate four to five letters, it would be expected that peripheral loss would have no special effect on the contrast requirements for reading (Rubin and Legge, 1989). But peripheral field loss may also be accompanied by a reduction in central visual function. Contrast sensitivity may be reduced in glaucoma, retinitis pigmentosa and other diseases which primarily affect peripheral vision (Rubin and Legge, 1989).

The size of the letters is a crucial factor with a direct effect on how legible a text will be for the visually impaired (Shaw, 1969), whether the text in question is printed or one which appears on a computer screen. Near acuity measured with Sloan M cards (Sloan and Brown, 1963) is a good predictor of optimal character size in reading (Legge et al., 1985b). For the clinician or teacher wanting to prescribe print size and viewing conditions or decide whether a particular sample of print is in appropriate size, the most popular systematic approach today is to measure reading speeds for print of different sizes to determine the smallest print that allows for the maximum reading speed (sometimes called the 'critical print size') (Bailey et al., 2003).

Font, print style, print layout, contrast, luminance, colours, and the presence of sources of glare contribute to the visibility of printed material and influence the decision about when the print size is appropriate. Also important are the visual characteristics of the reader (Bailey et al., 2003). Many studies have examined the relation between print size and reading speed in low vision. Generally, it is noted that maximal or near-maximal reading speed is achieved over a range of several print sizes, but speed slows progressively as the print size becomes smaller and approaches the individual's limit of resolution. The same general pattern is seen in sighted readers (Bailey et al., 2003).

Lueck et al. (2003) studied the relationship between the reading speed and the font size used. Participants present a variety of reading speeds. Those with good enough visual acuity were the faster readers, and their reading patterns were different from those of the slower readers. In the same study the fastest reader read words at 70 wpm and text at 138 wpm in the optimal print size. However, there was a 39 per cent reduction in the maximum reading speed for words and a 40 per cent reduction of the maximum reading speed for text when the print was not at the optimal size. This difference in reading speeds with a less-than-optimal print size was more evident for the faster readers than the slower readers. The slower readers read slowly across all the print sizes for words and text until their reading speeds dropped suddenly, after which they could no longer read the smaller print.

Altering the size of the letters is a very useful function, but choosing a very large font size, which can be recognized by most people with impaired vision, is not a solution. It is no use our giving a text in large letters to be read by an individual who is capable of reading smaller letters, since large letters can be hard to read and in the end slow down the reading process. Students with lower visual acuity need much larger print sizes. However, when letters reach a very large angular size, extra eye movements, and perhaps even head movements, may be needed to read a word or a meaningful phrase (Lueck et al., 2003).

Format factors, such as the width of the rows and the number of rows per page, can affect reading speed. Typesetting features, including the choice of font, kerning (the space between letters), and leading (the space between rows) may affect the legibility of print and influence reading speed (Arditi, 1999a).

The choice of font in aids for the visually impaired can affect legibility of text. The fonts chosen must consist of readily recognizable characters. There are differing views also about the style of type suitable for partially-sighted children, with Meares claiming that serifs (the decorative feet on printed letters) maintain a clarity of outline which stems the encroachment of the white and prevents the thinning of the letters (Meares, 1973, cited in Davies, 1989). Harrison (1978, cited in Davies, 1989) believed that children read most easily the typeface with which they are most familiar. In practice, however, he found that sans serif typefaces were most often chosen by teachers for the beginning reading level because they approximate more closely to the characters which children have to write. More recent data (Arditi, 1999a) shows that complicated, decorative or cursive fonts should be avoided as should those with 'dense' characters (a small distance between individual characters) and those containing characters with sharp points. Also to be avoided are the use of italics and underlining. Standard serif or sans-serif fonts, with familiar, easily recognizable characters, are best. Also, there is some evidence that sans-serif fonts are more legible when character size is small relative to the reader's visual acuity (Arditi, 1999a).

The line spacing and the character spacing are also factors which can affect legibility of a text, and

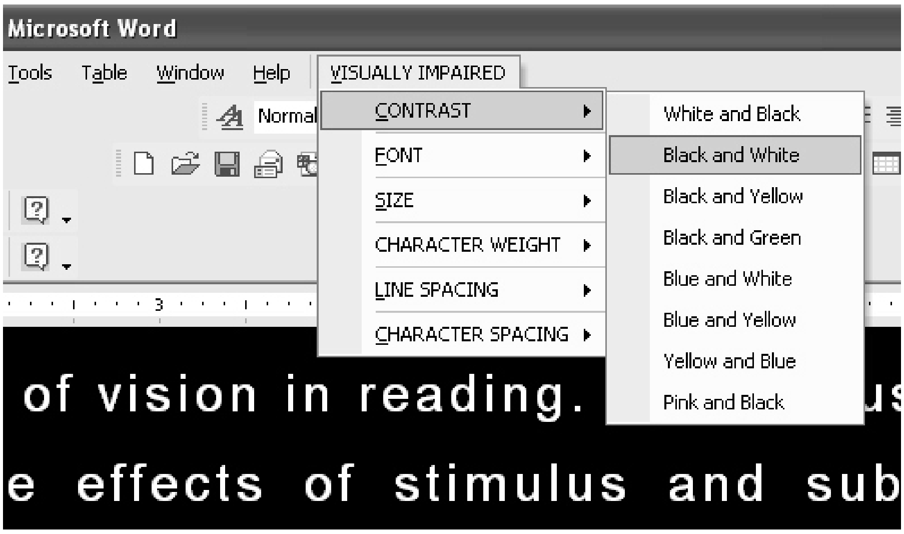

Figure 4: The options in the Microsoft Word Visually Impaired menu. There are sub-menus which offer options for contast, font name, etc. The illustration shows the options for contrast

provision must be made for their use. Harrison was unconvinced that larger spaces between letters, words and lines increased legibility (Harrison, 1980, cited in Davies, 1989). However, according to Gaster and Clark (1995), increased leading, or white space between lines of type, makes a document more readable for people with low vision. According to Arditi (1999a), spacing between lines of text should be at least 25 to 30 per cent of the point size. This is because many people with partial sight have difficulty finding the beginning of the next line while reading. Additionally, letters that are too close together are difficult for partially-sighted readers (Gaster and Clark, 1995), especially those with central visual field defects. Spacing needs to be wide between both letters and words (Arditi, 1999a; Gaster and Clark, 1995). Harrison thought that the most important factor for children's books was the unjustified line (i.e. the printer has not varied the space between the words to produce a straight margin down the right-hand side of the page) (Harrison, 1980, cited in Davies, 1989). Unjustified text may be easier for poorer readers to understand because the uneven eye movements created in justified text can interrupt reading (Muncer et al., 1986).

Shaw (1969) found relationships between the pathological conditions that caused the reduced vision and the preferences. Participants with glaucoma preferred bolder type and were most affected by typographical changes, especially size and weight. Participants with cataracts were helped more by increases in weight than increases in size, while this characteristic was reversed for participants with myopia. Finally, participants with age-related macular degeneration (AMD) were helped by increases in size and a change to a sans-serif typeface. Moreover, there were no cases in which typographical changes were helpful to one group and detrimental to the others.

The adapted tool

Considering all the above, we created a special adapted tool, which we believe is able to provide solutions to the issues under question. The tool was designed in visual basic and is an adapted option menu for Microsoft Word, which functions as an 'Add-In' to the basic Microsoft software.

Our analysis of the various factors in the preceding section has made it clear that there is a need to adapt the design of aids for the visually impaired. In the software which has been developed there is a broad selection of options in the following fields: background and text colours (contrast), font size, font name, weight of characters (bold, normal), line spacing, and character spacing. The various options are presented to the user through sub-menus contained in the Visually Impaired option installed on the top-menu of Microsoft Word (see Figure 4).

By opening the Contrast sub-menu we have the choice of eight different colour combinations of background and text, intended to cover the whole range of needs of the visually impaired. The characteristics of each colour – hue, lightness, saturation – have been suitably selected to provide the maximum possible contrast. The combinations of colour used are as follows: white background with black letters, black background with white letters, black background with green letters, black background with yellow letters, blue background with yellow letters, blue background with white letters, yellow background with blue letters, pink background with black letters. There are sub-menus which offer options for contrast, font name, etc. Figure 4 shows the options for contrast.

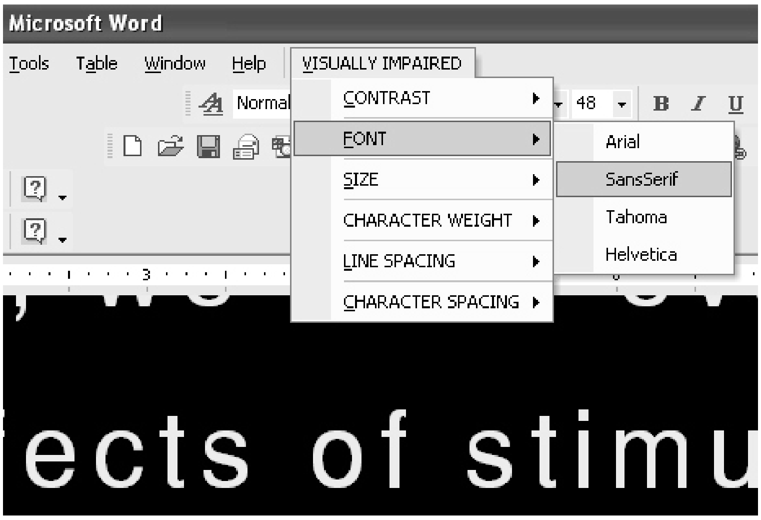

Figure 5: The Font sub-menu contains the font options suitable for use by the visually impaired

The Size sub-menu allows the user to choose the font size, from a range of 12 different settings. From the lowest setting of eight points, the sizes rise through 10, 18, 22, 28, 36, 44, 52, 60, 68, 76 to 84 points. The Font sub-menu offers four options: Arial, Helvetica, Tahoma and San Serif (see Figure 5).

Under line spacing, there are 10 different options. There are three basic options, single, 1.5 lines and double, plus another seven: 15, 18, 24, 32, 45, 65 and 80 – all with the ‘at least’ option. Under character spacing, there are 11 different options: condensed 2 and condensed 1, normal and expanded 1, 2, 3, 4, 5, 6 and 7. Since not every line spacing and character spacing option is appropriate for the various font sizes, the software performs an automatic adjustment to ensure the text is clearly legible.

Another important feature of the software is that it allows the user to save his choice of settings, sparing him the need to return to the menus at the beginning of each session. The settings selected are saved in a data base file under each user’s own code or name. This approach is of great value to the teacher: at the beginning of the school year he can conduct tests to determine the value of the above parameters and then enter them in his software along with the name and code number of each student, so that the values will appear on the screen automatically whenever the teacher or user types in the name or code. And, of course, if the visual ability of the student gradually changes, the values can be adjusted at regular intervals to reflect this.

Conclusion

The selection of predetermined options on the basis of the standards to be found in the international literature will solve significant problems. For the visually impaired it is not necessary to search by themselves through a whole host of options before choosing the one which suits them. For teachers, it is not necessary to acquire specialist knowledge of information science and software applications for the visually impaired. The software we have described solves a particularly serious problem for teachers working in schools for the sighted, since in most countries the vast majority of teachers will not have the necessary level of specialist knowledge to support visually-impaired students in a regular school. Using the tool which has been designed minimizes the need for special knowledge of Microsoft Word. This makes things easier for both the visually impaired and the teachers, since the choice of the correct parameters can be made by someone with only a beginner’s level of training on the software in question.

By using the additional choice – Visually Impaired – that appears in the top-menu of Microsoft Word, there is a significant saving in the time required for selection of the desired settings. A test conducted with five visually-impaired individuals in Greece yielded highly encouraging results. While choosing a setting for each category, and for one use only, took an average of 2.96 minutes, using the special tool reduced the time to an average of just 0.88 minutes. In this first case the subjects had been asked to choose specific settings, not to find the most suitable; the difference in time required increased dramatically when the visually-impaired participants tried to determine the most appropriate settings for their own sight, since they were obliged to try a large number of different options. The five individuals were all over 20 years of age and had been using a computer for at least four years and Microsoft Word for at least two years. In the first phase the participants were asked to use screen reading software to select specific values for contrast, font size, font name, weight of characters (bold, normal), line spacing and character spacing. In the second stage we asked them – with the same screen reading software – to use the tool to select specific values.

Texts can also be printed as educational material for the visually impaired, thus easing the task of the teacher. Using the tool we have described means there is no need for repeated trial-and-error printings before the appropriate parameters are found. The process can be completed easily and quickly on the computer screen, identifying the best settings for each individual and storing them for future reference.

We are not, of course, suggesting that the tool presented here can replace the use of the screen magnifier software; nevertheless, it can serve as an alternative aid, particularly for use by regular classroom teachers and by the visually impaired working at home. Its advantages include its ease of use (it requires no special training) and low cost (we have not yet decided on a price, but there has been discussion of the possibility of offering it free of charge to visually-impaired users).

References

Arditi, A. (1999a) *Making Text Legible: Designing for People with Partial Sight*. New York: Lighthouse International. Accessed 21 December 2004. [http://www.lighthouse.org/ print_leg.htm]

Arditi, A. (1999b) *Effective Color Contrast: Designing for People with Partial Sight and Congenital Color Deficiencies*. New York: Lighthouse International. Accessed 21 December 2004. [http://www.lighthouse.org/color_contrast.htm]

Bailey, I.L., Lueck, A.H., Greer, R.B., Tuan, K.M., Bailey, V.M. & Dornbusch, H.G. (2003) 'Understanding the relationships between print size and reading in low vision', *Journal of Visual Impairment & Blindness*, 97(6), 325–34.

Corn, A.L. & Wall, R.S. (2002) 'Access to multimedia presentations for students with visual impairments', *Journal of Visual Impairment & Blindness*, April, 197–211.

Corn, A.L., Wall, R.S., Jose, R.T., Bell, J.K., Wilcox, K. & Perez, A. (2002) 'An initial study of reading and comprehension rates for students who received optical devices', *Journal of Visual Impairment & Blindness*, 96(5), 322–34.

Davies, J. (1989) 'Reading schemes for partially sighted beginning readers', *British Journal of Visual Impairment*, 7(1). Accessed 21 March 2005. [http://www.visugate.biz/bjvi/1989/spring1989.hltml]

Eperjesi, F., Fowler, C.W. & Kempster, A.J. (1995) 'Luminance and chromatic contrast effects on reading and object recognition in low vision: A review of the literature', *Ophthalmology Physiological Optics*, 15(6), 561–8.

Fine, E.M. & Peli, E. (1995) 'Enhancement of text for the visually impaired', *Optical Society of America*, 12(7), 1439–47.

Gaster, L. & Clark, C. (1995) *A Guide to Providing Alternate Formats.* West Columbia, SC: Center for Rehabilitation Technology Services.

Gerber, E. (2003) 'The benefits of and barriers to computer use for individuals who are visually impaired', *Journal of Visual Impairment and Blindness*, September, 536–50.

Kelley, P. (1998) 'Technology', in P. Kelley and G. Gale (eds), *Towards Excellence: Effective Education for Students with Vision Impairments*, pp. 218–26. Sydney: North Rocks Press.

Legge, G.E., Pelli, D.G., Rubin, G.S. & Schleske, M.M. (1985a) 'Psychophysics of reading, I: normal vision', *Vision Research*, 25(2), 239–52.

Legge, G.E., Rubin, G.S., Pelli, D.G. & Schleske, M.M. (1985b) 'Psychophysics of reading, II: low vision', *Vision Research*, 25(2), 253–66.

Legge G.E., Rubin G.S. & Luebker A. (1987) 'Psychophysics of reading, V: the role of contrast in normal vision', *Vision Research*, 27, 1165–77.

Lueck, A.H., Bailey, I.L., Greer, R.B., Tuan, K.M., Bailey, V.M. & Dornbusch, H.G. (2003) 'Exploring print-size requirements and reading for students with low vision', *Journal of Visual Impairment & Blindness*, 97(6), 335–54.

Muncer, S.J., Gorman, B.S., Gorman, S. & Bibel, D. (1986) 'Right is wrong: An examination of the effect of right justification on reading', *British Journal of Educational Technology*, 1(17), 5–10.

Nebulus (1999) Hue, saturation and luminance. Accessed 20 February 2005. [http://www.nebulus.org/tutorials/2d/pictpub/hsl]

Pattillo, S.T., Heller, K.W. & Smith, M. (2004) ‘The impact of a modified repeated-reading strategy paired with optical character recognition on the reading rates of students with visual impairments’, *Journal of Visual Impairment & Blindness*, 98(1), 28–46.

Rex, E.J., Koenig, A.J., Wormsley, D.P. & Baker, R.L. (1994) *Foundations of Braille Literacy*. New York: AFB Press.

Rubin, G.S. & Legge, G.E. (1989) ‘Psychophysics of reading, VI: the role of contrast in low vision’, *Vision Research*, 29, 79–91.

Shaw, A. (1969) *Print for Partial Sight* (Research project). London: Library Association.

Sloan, L.L. & Brown, D.J. (1963) ‘Reading cards for selection of optical aids for the partially sighted’, *American Journal of Ophthalmology*, 55, 1187–99.

Stamopoulos, K. (1999) Intelligent monitoring of isolation cubicles. Thesis for MSc, Department of Electrical Engineering, University of Liverpool, UK.

Vaughan, D., Asbury, T. & Cook, R. (1971) *General Ophthalmology*, 6th edn. Los Altos, CA: Lange Medical Publications.

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