ANEC REPORT

"NEW STANDARD FOR THE VISUAL ACCESSIBILITY OF SIGNS AND SIGNAGE FOR PEOPLE WITH LOW VISION"

(ANEC-DFA-2008-G-044-Annex 6rev)

FINAL REPORT

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Project commissioned by:

ANEC, the European consumer voice in standardization, AISBL, Avenue de Tervueren 32, box 27, B-1040-Brussels, Belgium

Project execution:

-Ghent University, Faculty of Medicine and Health Sciences, Department of Movement and Sports Sciences

-Centre for Visual Rehabilitation of the Department of Ophthalmology, Ghent University Hospital

-Department at Ophthalmology, Ghent University Hospital

Research team:

Prof. Matthieu Lenoir, Department of Movement and Sport Sciences, Faculty of Medicine and Health Sciences, Ghent University (project supervisor). Watersportlaan 2, B-9000 Gent, Belgium. Tel 00 32 (0) 9 264 63 24. Matthieu.Lenoir@UGent.be

Inge Segers, orthoptist and rehabilitation/low-vision therapist at the Centre for Visual Rehabilitation of the Department of Ophthalmology, Ghent University Hospital (scientific collaborator). De Pintelaan 185, B-9000 Gent, Belgium. Tel 00 (0) 9 332 10 58. Inge.Segers@uzgent.be

Dr. Berry P.L.M. Den Brinker, Faculty of Human Movement Sciences, VU University Amsterdam (ANEC supervisor)

Prof. Philippe Kestelyn, ophthalmologist and head of Department at Ophtalmology, Ghent University Hospital.

Prof. Bart Leroy, ophthalmologist-ophthalmic geneticist at the Department of Ophthalmology, Ghent University Hospital.

Doctor Inge Joniau, rehabilitation ophthalmologist at the Centre for Visual Rehabilitation of the Department of Ophthalmology, Ghent University Hospital.

Doctor Sophie Walraedt, rehabilitation ophthalmologist at the Centre for Visual Rehabilitation of the Department of Ophthalmology, Ghent University Hospital.

Ludwine Wouters, coördinator and rehabilitation/low-vision therapist at the Centre for Visual Rehabilitation of the Department of Ophthalmology, Ghent University Hospital.

TABLE OF CONTENTS

PART ONE: LITERATURE OVERVIEW

PART TWO: EXPERIMENTAL STUDIES

REPORT SUMMARY

ANEC-DFA-2008-G-044-Annex 6rev

The main aim of this study was to provide an impulse for the development for guidelines for a) the advised size of signs (words, abbreviations, and icons) in public spaces, b) the advised contrast intensity between the elements of an icon/word/ abbreviation (local contrast between sign elements and immediate surroundings). A literature overview showed that a large amount of factors have to be reckoned with on the road to the development for such guidelines. The observation that, within the EU, a large variability in standards for visual accessibility exists underlines the need for scientific research on this issue. With respect to the specific research aims of this study, the overview shows that guidelines for the size of signs in public spaces differ significantly over EU countries, ranging from 1.5 to 6% of the critical reading distance. With respect to contrast guidelines, the picture is troubled due to the inconsistencies in definitions and calculations of contrast, although there is a general agreement on aiming at a maximal contrast for signage in public spaces (part 1).

Forty-two volunteers (40 persons with low vision and 2 control participants) participated in this study. In a first experiment, they had to identify signs, with different sizes and contrast intensities, presented on the same location in their central visual field. In a second experiment, they had to search for a specific sign in a cluttered visual environment and identify it. Response accuracy and response time were measured.

Our results with respect to size of the signs in general show that signs should be at least 5% of the reading distance (Den Brinker et al, 2008). Optimal –but not maximal- performance was observed when contrast intensity approached a value of 75% on the white-black axis (part 2). From this study, and in particular from the interaction between size and contrast, it is clear that these two factors cannot be seen independently from each other when proposing guidelines for visual accessibility in public spaces. Importantly, these results can serve as a general rule of thumb, but further research must elucidate whether they are sufficient for every person within the low vision group, given the considerable heterogeneity in this group with respect to visual acuity and visual field restrictions (part 3).

General Introduction

In the countries of the European Union, life expectancy continues to increase. As a consequence, the number of patients with age-related low vision also increases. At the same time, people are more mobile and continue to be mobile until a higher age. However, the architectural design of our environment has become more and more complex in the last century, with an exponential increase in the number of signs and signage in and around public areas and buildings. These factors result in a growing number of (mainly) elderly people with low vision having difficulties in finding their way in public spaces. In contrast to this obviously problematic situation, no uniform cross-national standards for the visual accessibility of signs and signage are available in the European Union.

The first aim of this project is to provide a critical overview of the national standards -if available- for signs and signage in the countries of the EU. We corroborate those data with scientific data –also if available- on the legibility of signs and signage for normal vision, but most of all for people with low vision. The overview focuses on factors such as character height of text and symbols, foreground/background contrast, colour, reading distance, localisation, lighting and legibility.

In order to give a good start to the project, background information regarding definitions, prevalence and causes of low vision in the European Union has been gathered in the first part of this report. In the second part, two experiments will be described that were set up to explore the effect of size, contrast intensity, and the potential interaction between these factors, to supplement the information in part one. In part three, the main results of the study are summarized into an initial impetus towards the formulation of guidelines, which could in time result in a European standard on the legibility of signs and signage in public buildings/for public procurement, where examples of good practice are given as an illustration.

PART ONE: LITERATURE OVERVIEW

1. Definition and prevalence of low vision

1.1. Definitions of low vision

For each of the aspects of vision loss, the loss can vary from mild to profound or total. A search through the literature revealed a wide variety of definitions and descriptions. Definitions vary over countries and organizations. Three definitions will be discussed in order to establish a global understanding of low vision.

In the context of low vision services (visual rehabilitation centres) a patient with low vision is defined as 'a person who, after treatment and refractive correction, has an impairment of visual function, and has a visual acuity (VA) of less than 6/18 to light perception, or a visual field (VF) of less than 10 degrees from the point of fixation, but who uses or is potentially able to use vision for planning and/or execution of a task'. Such a definition boils down to a functional low vision (WHO/IAPB 1999-2005).

The categorization of visual impairment currently in use worldwide is based on the 10th revision of the World Health Organisation (WHO) International statistical Classification of Diseases, Injuries and Causes of Death (ICD-10).

Visual impairment includes low vision as well as blindness. Low vision is defined as visual acuity of less than 6/18, but equal or better than 3/60, or corresponding visual field loss to less than 20 degrees, in the better eye with the best possible correction[1]. Blindness is defined as visual acuity of less than 3/60 with best possible correction, or a visual field loss to less than 10 degrees around central fixation, in the better eye (Resnikoff et al, 2004). Low vision is equivalent to visual impaiment of category 1 and 2, blindness is equivalent to visual impairment categories 3, 4 and 5 (see tabel 1.1). (Vision 2020: the right to sight 1999-2005; http://www.vision2020.org/documents/ MainReport_Inside.pdf, WHO IAPB).

[1] A 2003 WHO consultation recommended that the definitions of blindness and low vision be amended, substituting 'presenting visual acuity' for 'best-corrected visual acuity'.

Table 1.1 Proposed revision of numbered categories of visual impairment by WHO[2]

Category	Presenting distance visual acuity	
	Worse than:	Equal to or better than:
Mild or no visual impairment 0		6/18[3] 3/10 (0.3) 20/70
Moderate visual impairment 1	6/18 3/10 (0.3) 20/70	6/60 1/10 (0.1) 20/200
Severe visual impairment 2	6/60 1/10 (0.1) 20/200	3/60 1/20 (0.05) 20/400
Blindness 3	3/60 1/20 (0.05) 20/400	1/60* 1/50 (0.02) 5/300 (20/1200)
Blindness 4	1/60* 1/50 (0.02) 5/300 (20/1200)	Light perception
Blindness 5	No light perception	
9	Undetermined or unspecified	

* Or counts fingers (CF) at 1 metre.

Next to the definitions of functional low vision and low vision of the WHO described above, the International Council of Ophthalmology (ICO, 2002) recommended the following terminology in its resolution:

‘Visual impairment is used when the condition of vision loss is characterized by a loss of visual functions (such as visual acuity, visual field, etc.) at the organ level. Many of these functions can be measured quantitatively. Low vision is used for lower degrees

[2] ICD update and revision platform: change the definition of blindness (http://www.who.int/blindness/en/)

[3] The visual values are given in the 6-meter metric notation (commonly used in Britain), the decimal notation (commonly used in Europe) and in the U.S. notation for 20 feet.

of vision loss, where individuals can be helped significantly by vision enhancement aids and devices. Blindness is used only for total vision loss and for conditions where individuals have to rely predominantly on vision substitution skills.

For reporting the prevalence of vision loss in population studies and clinical research, they describe vision loss in more detail by classifying it into multiple Ranges of Vision Loss (based on visual acuity, see table 1.2).

Table 1.2. Categories of visual impairment used by the ICO

Category	Specified measurement conditions (best-corrected, presenting or pinhole distance acuity) reported	
	Worse than:	Equal to or better than:
Normal vision		6/7.5 8/10 (0.8) 20/25
Mild vision loss	6/7.5 8/10 (0.8) 20/25	6/18 3.2/10 (0.32) 20/70
Moderate vision loss	6/18 3.2/10 (0.32) 20/70	3/48 1.25/10 (0.125) 20/160
Severe vision loss	3/48 1.25/10 (0.125) 20/160	3/60 1/20 (0.05) 20/400
Profound vision loss	3/60 1/20 (0.05) 20/400	1/60 1/50 (0.02) 5/300 (20/1200)
Near-total vision loss (near blindness)	1/60 1/50 (0.02) 5/300 (20/1200)	No light perception
Total vision loss (total blindness)	No light perception	

ICO points out that, if such detailed reporting is not feasible, the categories defined in ICD-10 of the WHO should be used as a minimum. The numbered ranges became part of ICD-9 (and now ICD-10), while the named ranges became part of ICD-9-CM, the ‘Clinical Modification’, which is the official U.S. Health Care classification for all diagnostic reporting.

There are a few differences between the two classifications. The first difference is the fact that ICD does not code normal conditions, while ICO does. Mild loss is a transitional range between fully normal vision and low vision. This is noted because the driver’s license requirements in the European Union demand a binocular VA of 0.5 (5/10) or a VA of 0.6 (6/10) if only one eye can be used (ICO, Visual standards, vision requirements for driving safety, Brazil 2006). According to ICO, the latter ranges of VA are categorised as mild vision loss (see table 1.2). Mild vision loss can be subdivided into ‘minimal loss’ (<0.8 and ≥0.5) and ‘mild loss’ (<0.5 and ≥0.32) (ICO visual standards, 2002).

In Belgium, inclusion criteria for the Centre for Visual Rehabilitation of the Ghent University Hospital are conformity with the WHO criteria by Resnikoff (2004) and table 1.1. However, it often occurs that patients with deviating clinical outcomes (for example person X with VA of 0.4 and normal VF or person Y with VA of 0.6 and VF of 60°) register at our service with (sometimes a lot of) complaints. Those people are, according to ICO, categorized respectively as having mild and minimal impairment, but they are also told that they don’t meet the drivers licence requirements ànd rehabilitation benefits. These people have identifiable visual impairments, not belonging in the categories entitled to low vision welfare benefits, but who are prohibited from driving a car because they are nevertheless labeled as visually impaired. From this example, it follows that it might be considered to recognize a low vision group that combines a ‘medium’ VA (above 0.3) and a restricted VF (but above 20 degrees), as is the case in persons X and Y described above.

Another discrepancy between the ranges defined for ICD-10/WHO and those for ICD-9-CM/ICO is the cut-off at 6/60 (see table 3). ICD-10 uses ‘less than 0.1 (20/200, 6/60)’, while ICD-9-CM uses the U.S. definition of ‘20/200 (0.1, 6/60) or less. Also in the range of profound vision loss (<0.05, <20/400, <3/60), the emphasis gradually shifts from vision enhancement aids to vision substitution skills (using other senses than vision). Because of the remaining visual potential, ICD-9-CM/ICO reports this under low vision, because of the profound loss, ICD-10/WHO group it with blindness.

This discrepancy may sometimes lead to the situation that in case of being categorized as ‘blind’ according to the less stringent standard, an individual has still a certain degree of visual perception.

Barry & Murry (2005) state that present differences in inter- and intranational classifications are one of the causes for inadequate registration of visual impairment, as will become clear in the next paragraph.

1.2. Prevalence and causes of low vision in the European Union

There is quite a variety in outcomes of studies reporting on the prevalence of (blindness and) low vision, which is mainly caused by the different methodologies (surveys, register studies, or a combination of both) used and the large sample size that is needed to achieve reliable prevalence data. In addition, most of these studies focused on blindness as well as low vision, which has proved to be often problematic with respect to misclassification (Grey et al., 1989). At the same time, some studies had other purposes (for instance Evaluation of non-medical costs associated with visual impairment in France, Italy, Germany and the UK by Lafuma et al, 2006) or are limited to a certain age group (e.g. Bergman et al, 2002; Buch et al, 2001).

So far as we are aware, no scientifically based study has been conducted solely in order to obtain ready-made, reliable prevalence data on low vision in the European Union. A significant proportion of blind people and people with low vision are not even officially registered as such. We refer to the reviews by Nillsen et al. (2003), Kocur and Resnikoff (2003) and Barry and Murray (2005).

The most recent estimates of the prevalence of visual impairment is done by Resnikoff et al in 2004. This article offers *estimates* of *global* data on visual impairment in the year 2002. For the continent of Europe, studies are used from 10 countries. In the case of countries for which data was scarce, national sources were investigated. All surveys had to meet stringent criteria: definitions classifiable within the ICD-10/WHO ranges of vision loss, discriptions of ophthalmic examinations and sample designs/plans. Table 1.3 demonstrates the estimates of visual impairment for the continent of Europe and the world.

Table 1. 3 Estimates of visual impairment in Europe and the world

	Europe	World
Population	877 886 000	6 213 869 000
No. of blind people	2 732 000	36 857 000
Prevalence of blindness (%)	0,3	0.57
No. of people with low vision	12 789 000	124 264 000
Prevalence of low vision (%)	1,4	2
No. of visually impaired persons	15 521 000	161 121 000

From our knowledge of ophthalmology and a review of scientific articles, the prevalence of blindness (and low vision) increases exponentially with age (Lafuma et al, 2006, Nissen et al, 2003). Resnikoff et al (2004) provides an overview of age-specific prevalence of blindness and the number of blind people. Figure 1.1 shows the number of blind persons in Europe within age-groups.

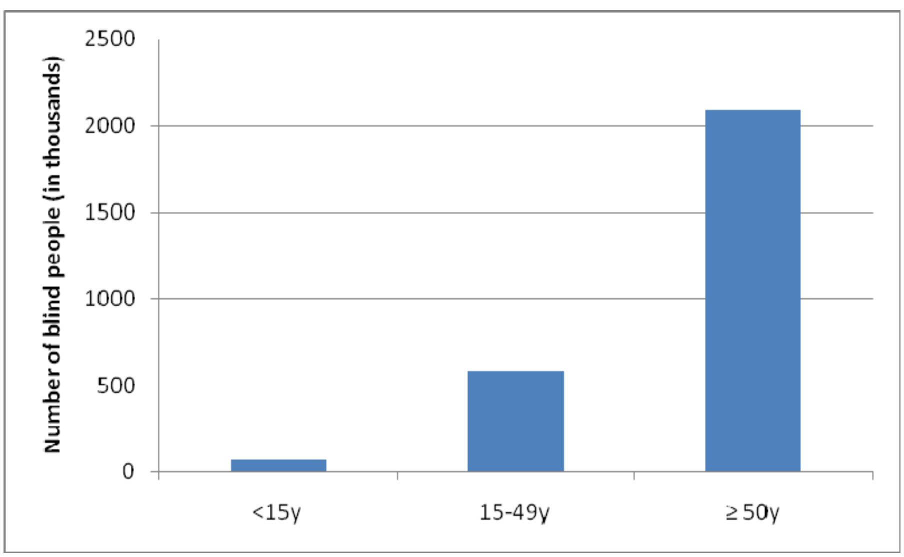


Figure 1.1: Number of blind persons in Europe in millions (from Resnikoff et al., 2004)

Due to the paucity of data on the age-specific prevalence of low vision, Resnikoff et al (2004) noted that it is not possible to construct a model with absolute figures similar to that described above for blindness. We can only presume that for low vision the construction is similar. Resnikoff et al (2004) also state that female/male prevalence ratios indicate that more women are likely to have visual impairment than men in every region of the world. However, Lafuma et al (2006), Bergman et al (2002), and Cidrone et al (2007) question this statement.

Globally, age related macular degeneration is the third leading cause of visual loss in adults, but in industrialised countries, age related macular degeneration is the major cause. The other conditions comprise cataract, glaucoma, diabetic retinopathy and uncorrected/uncorrectable refractive errors. In people of working age, diabetic retinopathy, retinopathy pigmentosa and optic atrophy are the most frequently reported causes of serious visual loss. In the middle income countries of Europe, advanced cataract, glaucoma and diabetic retinopathy are more frequently observed (Kocur & Resnikoff, 2002).

Finally, there is no information found regarding people with a visual acuity above the WHO defined low vision (0.3) but below the standard for driving a car (0.5), because of the more frequently used definition of the WHO, especially in recent reviews.

2. Definition of signs and signage

In order to clarify what is meant by the expressions “signs” or “signage” in this study and in order to understand the different guidelines prescribed by the different countries in the European Union, an assessment was made of how different countries deal with those terms. It is also useful to place this terms into a broader context, such as “universal design” or “design for all”, which automatically pop up in communication about visual accessibility.

Signs can contain pictograms, symbols or icons and text. This distinction will also be made in chapter 4. Vicente et al (2008; in the Spanish context) describe signs or signage as the purpose of all graphic composition to transmit a specific message. Designers use both image and text. In the UK (Barker et al, 2000), a sign is a means of conveying information about direction, location, safety or a form of action. Signs are most important to people who are unfamiliar with their environment or who need to know how to do something, such as find the exit or operate a door system. Signage can be split into four main categories: information signs (purely information), direction signs (from point a to b, always with an arrow), identification signs (names, …) and safety, fire and mandatory signs. Ireland (NDA, 2002) says that in an unfamiliar building, an adequate number of clearly legible, well-designed signs will help everyone to find their way around and are vital for people with speech or learning difficulties. Signs can indicate direction, alert to hazards or provide information. They can direct people to the best and shortest route to a particular part of an environment or building and, on long routes, should also provide confirmation of direction.

In an environment not previously experienced, the ease with which one can comprehend the spatial configuration of an interior space is a critical component of building coherence. In such a case, people rely on numerous types of environmental information to find their way. Environmental psychologist Gerald Weisman found that plan configuration was the most influential factor with respect of way finding, followed by spatial landmarks, spatial differentiation and finally signage and room numbers (Wilson et al, 2004).

A more recent review suggests also that humans rely on geometric visual information (hallway structures etc.) rather than non-geometric visual information (eg. doors, signs) for acquiring cognitive maps of novel indoor layouts.

Results of a study by Legge et al (2008) indicate that partially sighted and older normally sighted participants relied on additional non-geometric information to accurately learn layouts. In conclusion, visual impairment and age may result in reduced perceptual and/or memory processing that makes it difficult to learn layouts without non-geometric visual information.

Due to the increased life expectancy of the older-aged population and the increasing prevalence of chronic diseases including visual impairments, signage is necessary and should be provided in such a way that it is readable for everyone. Criteria for designing an environment which is accessible for disabled persons can also be contradictory. People who don’t speak the language benefit from the use of symbols, while people with a visual impairment may not recognise the small details of a symbol. Accessibility is therefore a relative term, being related to the functional, sensory or cognitive abilities of the person or group of disabled people in question (Toegankelijkheidsbureau, 2001). The recent developments in the “Desing for All” approach to accessibility entails that the requirements of as wide a range of users as possible are taken into account in the planning, design, construction and management of a building or facility. This will meet the needs of almost all users, including disabled users, older people, children, parents with buggies etc. most of the time.

3. Research methods for the literature review

Information for the literature overview was obtained a) from national guidelines of EU countries, and b) from scientific literature on this issue. In order to locate guidelines or standards on visual accessibility, we researched all potential sources. Searches were conducted in any type of published and unpublished literature and include conference papers or abstracts, governmental and technical reports, standards or best-practice documents, …. The keywords used were specifically low vision, accessibility, orientation, public spaces, names of European Countries and many more. No limits were set on the year of publication, because of the lack of available literature.

Scientific literature searches were conducted on the following databases: Web of Science, ScienceDirect and Pubmed. The keywords used were contrast, sensitivity, colour contrast, legibility, characteristics of type faces, visual acuity, visual impairment, accessibility, built environment, …. Questions about contrast and contrast sensitivity, colour, functional measurements and many more concerning the experimental phase of the study, could be solved by internal contact with doctors (experienced in research or rehabilitation) and research assistants.

A lot of material and information about guidelines was obtained through personal contacts. An attempt to retrieve e-mail addresses from our Health Department of all Health Departments of the European Union was answered with 16 addresses, while no e-mail addresses could be obtained. Because of the lack of time for data collection, the search was continued for e-mail addresses. Other interesting sources, because of the need for guidelines for public procurement, were the Ministry of Mobility and Public Work and private architects. A document was found on the internet, called 'European Concept for Accessibility' (Aragall, 2006). This document contained a list of the EuCAN members, a number of partners who share a strong commitment to the improvement of accessibility in the built environment. A selection of members professions: architects, project managers of Design for all, researchers, professors, members of councils of organisations of disabled people, was also contacted. Nearly all countries (23) were contacted by e-mail, of which 20 countries are member of EU. See table 1.4 for the final response of these countries.

<u>Table 1.4.</u> Overview of the responses of the EU countries

Country	Information received
Sweden (SWE)	Link to website Handisam, the Swedish agency for disability policy coordination. Via another contact, link to (22).
Belgium (BE)	Situation in Belgium (new accessibility law 01/03/2010). Lack of information about current topic.
Italy (IT)	We will collect information. Later: only visual accessibility on public roads is available
Germany (DE)	We will collect information about a current development on contrasts. Later: no progress to expect this year about standard
Serbia	Link to (29). (not an EU-member)
Portugal (PT)	Link to Barker et al (1995) Building Sight and other institutions.
Switzerland	Link to (55). (not an EU-member)
Ireland (IRL)	Link to (13) and recommendations of NCBI - working for people with sight loss. Link to National Disability Authority 2002: Building for everyone, inclusion, access and use (nr 46).
Slovenia (SL)	Link to another contact person. No answers to mails.
Norway (NO)	Link to (50).
Austria (AT)	Book Praxishandbuch zum Bundesvergabegesetz 2006 does not content special information about how to improve legibility and readability of signs. No other recommendations.
United Kingdom (UK)	Link to (6).

4. Overview of the the legibility of signs and signage in the European Union

During the survey, a very large variation in guidelines was found. Additionally, "signage" often was a small topic into the general norms for access to the built environment. With respect to accessibility of signage for visually impaired people, the term legibility includes not only character height and contrast. The following factors that can affect legibility are also discussed below: character size, symbol size, letter form, space between letters, space between words, space between lines, contrast, positioning and lighting. The order of presentation does not represent any particular relative importance of each factor. Due to the variability and in addition the lack of explanation and establishment of some guidelines, the literature survey is supported by a review of scientific data about the different factors and psychophysical variables contributing to the legibility of signs.
For the purpose of comparison between countries, absolute figures have been converted to ratios whenever possible (e.g. a recommended letter size of 15 cm at a reading distance[4] of 4 m becomes 3.75% of reading distance). Occasionally, reference values of some non-EU countries are also given.

4.1. Character size

Information from nine EU countries concerning the size of a character was found. The minimal ratio character size-reading distance varied from 1.8% (DE) and 2% (BE and SWE) to 6% (IRE), with an average value of 3.5%. In some countries the character size is related to other factors. The Netherlands guideline stipulates that a 5% ratio (Den Brinker et al, 2008) is acceptable on condition that a minimal contrast between letter and background of 1:3 is attained (Wijk, 2008). In Belgium the recommended character size is dependent on the importance of the information: the 2% guideline for people with low vision is increased to 4% when important information is to be presented (Toegankelijkheidsbureau, sd). The guidelines do not stipulate in detail what information is considered important or not.
The UK provides an indication of the minimum character sizes for close-up (1.5-2.5 cm), medium (5-10 cm) and long-distance (>15cm) viewing. The National Council for the Blind of Ireland, who have based their recommendations on the research done by

[44] Reading distance is the critical distance from which the information contained in the letters or signs must be readable for people with low vision.

the Joint Mobility Unit of the Royal National Institute of the blind (RNIB) and the Sign Design Society of the UK, confirms character sizes for close-up and medium distance reading, but complement the sentence: the greater the distance between the sign and the reader, the larger the character height. A ratio of 6% of the reading distance is recommended in mm (at 4 m: 240 mm and at 1m: 60 mm character height). The Sign desing guide of the UK presented their data for maximum legibility in a graph and according to visual acuity. Figure 1.2 shows the relationship between character size and critical reading distance for people with 6/9 VA (approximated to the UK standard for driving) 6/60 and 3/60 VA. For example, below the 3/60 line, someone with 3/60 VA would probably not be able to read the text (Barker et al, 2000). In absolute figures, for people with low vision, minimal ratio character size-reading distance character heigt should be about 4 to 6 percent.

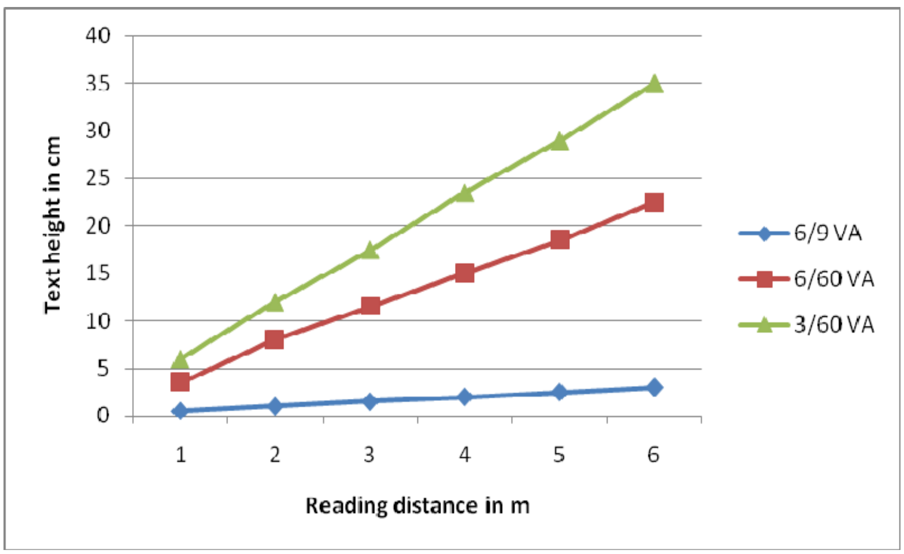


Figure 1.2: Height versus distance chart (Barker et al, 2000)

Portugal specifies no reading distance, but proposes an absolute minimum character size of 6 cm. Several other countries also provide similar rules of thumb. Character size on computer screens should never be smaller than 3mm (BE), and never <5cm for road signs (BE). House numbers should always exceed 15cm of height (IRE and SWE). Swedish (Svensson, 2008) guidelines also point to the fact that character size cannot increase infinitely, because text is not readable anymore for people with a reduced field of view, when they are too close to the sign. Den Brinker et al (2008) noted that the two WHO criteria for comfortable reading cannot be met at the same time: an acuity reserve of 3:1 results in a character height of 5 degrees, which is too big for a minimal field of view of 10 degrees. Therefore, they proposed the 5% of critical reading distance as a fairly good compromise (Den Brinker et al, 2008). Germany guidelines are in agreement with Sweden and are expressed in viewing angles[5] (see figure 1.3 and 1.4).

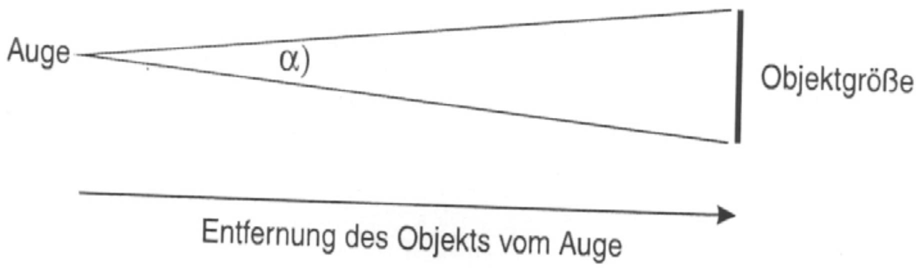


Figure 1.3: Viewing angle α

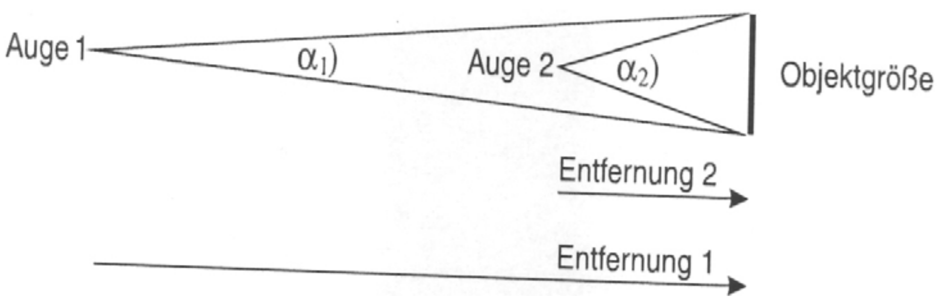


Figure 1.4: Example of increasing viewing angle α_2 (Lindner et al., 1999)

In practice, there is no purpose in exceeding the viewing angle of two degrees. In the following table they show the minimum viewing angles to three priorities, on the basis of the research ‘Kontrastoptimierung’ (Lindner et al, 1999; Table 1.5), which is the basis for the German guidelines with respect to character size. Once the viewing angle is known, the correct reading distance for that specific sign must be identified. Figure 1.4 displays how the character height should be calculated. It is notable that in these and many other guidelines, the visual characteristics of the intended users is

[5] The viewing angle is the angle between the outermost points of the boundery of an object and their intersection in the eye. It takes into account the viewing distance to each object and the size of the object (BMG, 1996). By increasing the viewing angle, the visual perception of an object improves until the perceived object becomes too large, which is usually problematic for people with visual field restrictions . See also figure 1.3 and 1.4.

not systematically specified. It is clear that a guideline for viewing angles cannot be proposed as a general guideline without specification of, among others, the visual acuity and visual field characteristics of the users.

Table 1.5. The minimum viewing angles to three priorities (Lindner et al, 1999)

Priorities	Visual angle	Examples
Priority 1: **warnings and emergencies**	2 degrees for visual signs and text	Emergency exit, escape route, …
Priority 2: **decision functions**	1.5 degrees for visual signs, 1 degree for text	Timetables, housenumbers, …
Priority 3: **guiding functions**	1 degree for visual signs, 0.8 degrees for text	Continuous markers of roads and walls

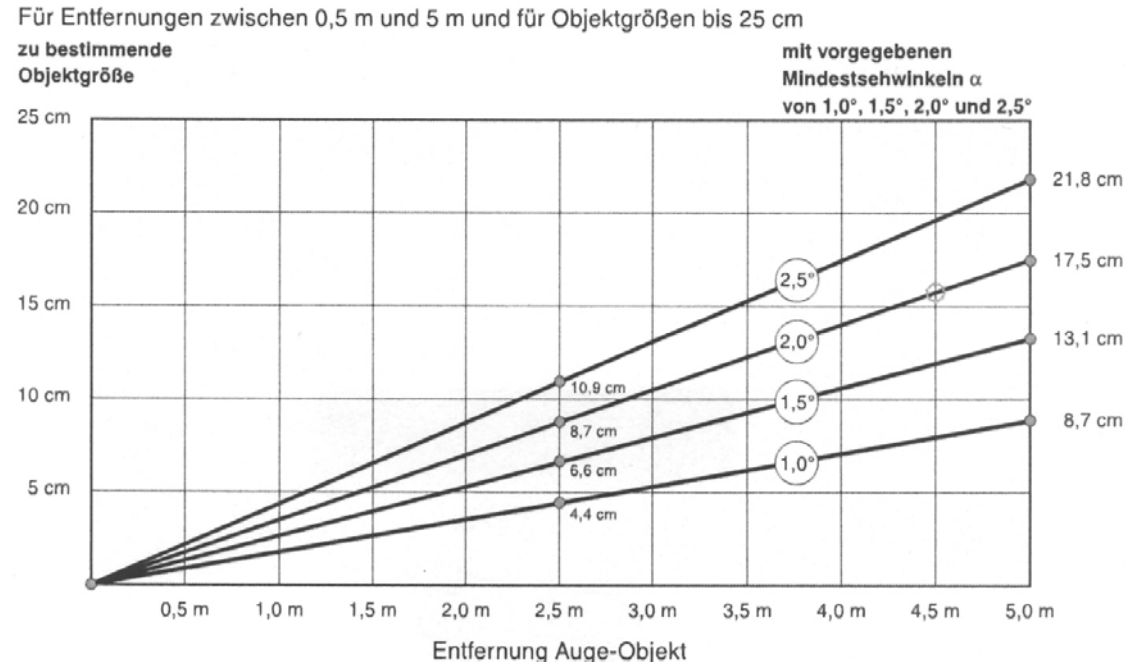


Figure 1.5: Determination of character height with the visual angle depending on reading distance

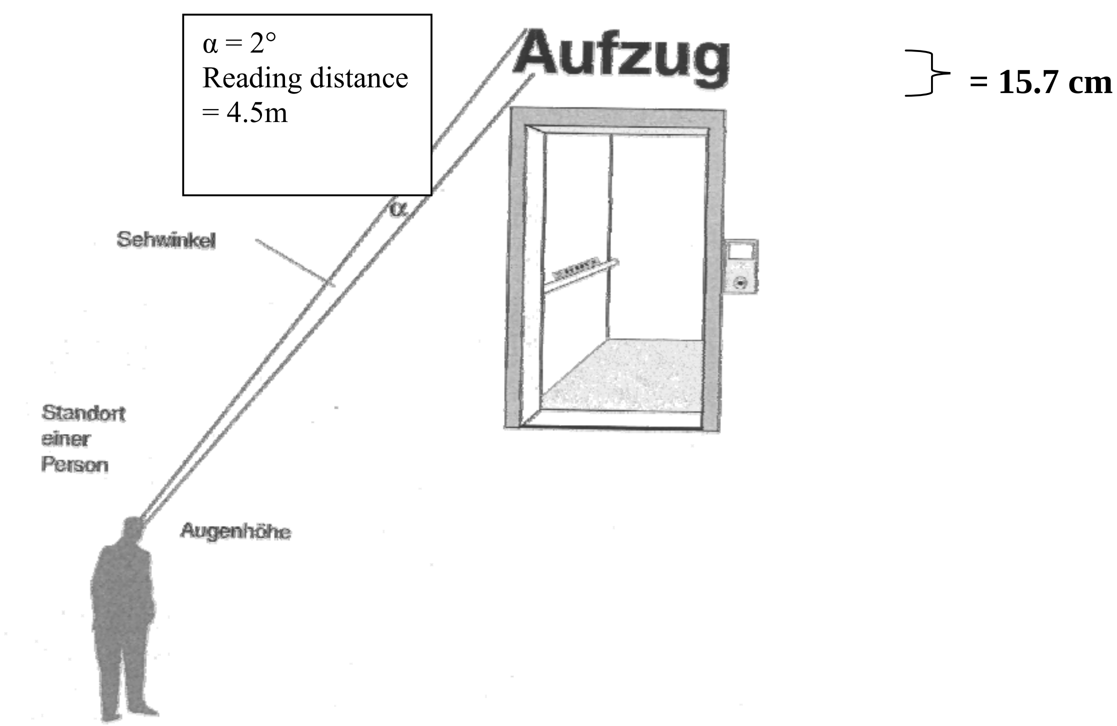


Figure 1.6: Illustration of the relationship between critical reading distance, viewing angle, and character height.

If a person needs a viewing angle of two degrees to recognize an emergency sign (priority 1) and this sign should be readable at a 4,5m distance, character height must be 15,7cm. Converted into ratios and taking into account the three priorities and reading distance, the recommended character height should be between 1.8 and 3.5 percent of the reading distance.

Non-EU countries, which are not included in table 1.7, show varied guidelines concerning letter size. The recommended ratio letter size-reading distance varies from 1% in Serbia to 3% in Switzerland. Norwegian guidelines note that letter size should be 3.5 cm for orientation signage and 5.5 cm for reference and door signs. This minimum limit is also applied in the US, where letter size should be 7.5 cm in general. US and Canadian guidelines remain mainly unclear and find character height suited to intended viewing distance: the larger the size, the greater the legibility for everyone.

Important clinical studies and scientific articles about character height in low vision population are lacking. Den Brinker et al (2008) derived specific information from the definition of low vision of the WHO and from generally accepted recommendations for comfortable reading, that character height should be 5 percent of the critical reading distance.

Table 1.6. Overview of the recommended letter size in the EU countries

Country	Recommended ratio letter size / reading distance	Remarks
BE	2-4%	Depends on importance of information displayed
NL	5%	Contrast letter vs. background must be minimal 1:3
LUX	3.75%	
IRL	6%	Absolute minimum of 1.5-2.5 cm
UK	Average of 5%	See figure 2
ESP	2.75% (minimum 1.4%)	
SWE	2% (minimum 1.5%)	
PRT	Minimum 6 cm	Distance (not specified)
DE	1.8-3.5%	Visual angle 1° - 2°. Max distance in common space for text is 15m.
AT	-	No guidelines about visual accessibility available (?)

4.2. Symbol size

Only four European countries specify symbol size. The UK claims that, where space permits, symbols should be at least 10 cm in height overall. It is not quite clear if symbol size should also be calculated like text, according to figure 1.2. The UK also states that well recognized symbols are often better than words for most types of vision. Belgium even stipulates that information with text should be supplemented with symbols to facilitate comprehension for everyone. The Netherlands guideline stipulates that 5% from critical reading distance is acceptable. The Germans specify that signs should be 0.2 to 0.5 degrees bigger than text with the same priority (table 6). Other non-European guidelines suggest a symbol size of 20 cm x 20 cm (NO) and 15.2 cm (CA and US).

There appears to be standardization about symbols or icons. Most of the guidelines recommend the use of ‘international approved and standardized icons’, for example ISO 7001:2007, BS[6] 8501:2002 or SS[7] 30600:2008. However, it seems to be very difficult to lay hands on those standards. Additionally, there is no legislation towards signalisation in private or public buildings, except the European law 92/58/EEC of 24 June 1992 regarding the minimum requirements for the provision of safety and/or health signs at work. Minimum requirements such as form and colour are set (see table 8). Dimensions or measurements are not recorded, only the relationship between colour and background of a drawing are. A lot of existing symbols or icons contain small details, as is obvious in the figure below, in which the signs for ‘elevator’ and ‘information point’ are shown.

Figure 1.7. icons for ‘elevator’ and ‘information point’.

The small details of the lift are the basis for understanding, but a visually impaired person will have much more difficulty recognizing the symbol of the lift at a certain distance than the information symbol. Using this kind of symbols would thwart the comparison with words, where every character has the same thickness.

[6] British Standard
[7] Swedish Standard

Table 1.7 Minimum requirements for the provision of safety and/or health signs at work.

Colour	Meaning of purpose	Instructions and information
Red	Prohibition sign	Dangerous behaviour
	Danger – alarm	Stop, shutdown, emergency cutout devices, evacuate
	Fire-fighting equipment	Identification and location
Yellow	Warning sign	Be careful, take precautions Examine
Blue	Mandatory sign	Specific behaviour or action Wear personal protective equipment
Green	Emergency escape, first aid sign	Doors, exits, routes, equipment, facilities
	No danger	Return to normal

Scientific data about this topic are scarce although there is a study by Cook et al (2005), who investigated how to improve communication of emergency escape route information with respect to building users who are visually impaired. The design of the test was very interesting. In order to test legibility of signs, participants were asked to walk towards the sign and identify at which point they could make out any of the signs features. Such a real-life task combines two important characteristics of visual accessibility: a low vision person must be able to find the location of a sign (a process for which the contrast between the background and the (background within the) sign is important, and to identify/read the sign. Unfortunately, no information regarding height or measurements of signs were mentioned in the article, so no derivation could be made about ideal character height of emergency signalization.

Table 1.8. Overview of the recommended symbol size in the EU countries

Country	Recommended symbol size	Remarks
UK	10 cm in overall height	
NL	5% from critical reading distance	
IRL	At least 15 x 15 cm	emergency signs: should be sized larger, as they may need to be followed in smoky conditions or without good lighting
DE	1.8-3.5%	Visual angle between 1° and 2°.

4.3. Letter form

Information concerning letter form was obtained from eleven countries. Ten countries agreed on the choice of sans serif typefaces, one country did not mention letterform in its guidelines. Most recommended typefaces are Arial (BE, ESP, IRL, LUX, SWE, UK), Helvetica (DE, IRL, LUX, SWE, UK), Futura (DE, IRL, SWE, UK) and Frutiger (DE, ESP). Some countries say that seriffed letterforms are also legible, e.g. Times New Roman (UK, IRL).

In a review on the legibility of typefaces on printed text for readers with low vision, Campbell et al (2007) concluded that the effects of the presence or absence of serifs on the legibility of text seem to be inconclusive and does not enable us to make strong conclusions. Yet, on the basis of subjective preferences and comfort, sans serif typefaces tend to be more readable or legible than serif typefaces. Guijarro et al (2008) found with a sample group of 97 adults, sans serif typefaces Arial and

Tahoma provided faster reading speed in texts. The other two examined fonts, Comic Sans and Times New Roman, provided respectively slower and very poor results. Arial and Verdana were the most legible fonts in a research of Sheedy et al (2005). Times New Roman and Franklin were least legible.

Belgium, Germany, Ireland, Spain, Sweden, Ireland and the UK stipulate not to use only capital letters, but both small and capital letters for text on signs. In The Netherlands it is acceptable to use capital letters for short, familiar words (e.g. EXIT, WC). Arditi et al (2007) proved scientifically that upper-case is more legible than the other case styles, especially for visually impaired readers, because smaller letter sizes can be used than with other case styles, with no diminution of legibility. At larger sizes, the advantage of upper-case disappeared. With respect to letter size and abbreviations, it is important to note that individual letters are more easily identified than words. Lower case words must be 10-20% larger to have the same threshold legibility (Sheedy, 2005).

Several countries and previous research (Campbell et al, 2007) provide other factors that should be considered. Thickness of letters should be between 5-7 mm for Portugal and between 1/7 and 1/8 of letter size for Germany. Italic, underlined (LUX, SWE), condensed, decorative (UK, IRL) and too bold typefaces should be avoided. Spain says the internal white of letters and numerals should be large and open. In the study of Guijarro et al (2008) four typefonts have been compared with the bold. In this analysis, they had found that 51.5 percent preferred the normal type and 48.5 percent the bold. They concluded their research with the very true sentence 'we should not lose sight of the fact that the form of the message must never hide the content that in the end is the final objective.'

The Netherlands and Sweden highlight the fact that matrix letters (e.g. on electronic screens) are not readable for people with visual impairment, unless the pixels are small. Whatever the letter form, the number of pixels is also important. Bailey et al (1987) showed that readability significantly increases when the letters are more 'smooth' as opposed to 'grainy'. Since the publication of their results much progress has been made in digitally designing letters, abbreviations, and signs, so that the smooth/grainy aspect should not be an issue these days However, matrix screens with pixels too far away from each other still abound in public places.

4.4. Inter-letter space or kerning

Concerning Inter-letter spacing or kerning, Sweden stipulates that ‘inter-letter space should not be too increased’. On the other hand, Luxembourg states that ‘there should be a certain distance between letters’.

Other countries provide detailed regulations with specific dimensional requirements. According to Germany, inter-letter spacing is at its best when related to letter size (1/7th), although an appropriate distance for each font is recommended. The United Kingdom guidelines propose an inter-letter space between 20 and 30% or 12-14 letters per line (including spaces).

Campbell et al (2007) and Guijarro et al (2008) discuss evidence which points to an overall advantage in reading performance and a reduction in letter confusion with adequate letter spacing. Chung (2002) has shown that reading speed varies with letter spacing, peaking near the standard letter spacing for text and decreasing for both smaller and larger.

4.5. Inter-word space

Concerning inter-word space, we find references for adaptation. Inter-word space should be more or less equal to 3/7th of letter size (DE) versus inter-word space between 20 and 30% or 2-3 words per line (UK). SWE agrees with the the UK regarding not too many words per line, but stipulates that the space between words should not be too large. Can the findings for kerning be extrapolated to inter-word spacing? Accoording to Legge et al (2006), people with low vision appear to rely more on spacing information in sentences.

4.6. Inter-line space or leading

Two countries recommend inter-line space as 11/7th of letter size (DE). To improve legibility and readability, there should be a maximum 65 characters per line. In the UK, however an inter-line space of 15-20% is recommended, but without further explanation. Ireland mentions that the leading measurement is at least 3 points greater than text size; 12 point text should have a 15 point leading.

According to Chung (2004) increased vertical spacing, which presumably decreases the adverse effect of crowding between adjacent lines of text, benefits reading speed. This benefit is greater in peripheral than central vision. In his later study of 2008, he finds that increased line spacing in passages did not lead to improved reading speed in people with AMD.

The review study of Campbell et al (2007) notes that the choice of typefaces and an adequate use of the characteristics of fonts (kerning, inter-word space, leading) can affect legibility and reading performance of indiviuals with low vision, but is still open for debate.

4.7. Contrast

Contrasts are used to distinguish between a sign on its background. A high contrast with the background significantly contributes to the ability of the viewer to discriminate between important objects, in this case text or symbols on signboards. According to Lin et al (2009), Barker (2000), Cook (1999) and Legge et al (1990) text can be depicted by luminance contrast[8] and colour contrast[9].

Scientific research has shown that for normally sighted subjects, reading rates for high colour contrast are as fast as those for high luminance contrast. Data indicates that readers rely on information conveyed by colour contrast or luminance contrast, whichever yields the best performance. On the other hand, people with low vision read text faster with luminance contrast than colour contrast. This was true at maximum contrast but increasingly so at lower contrasts (Legge et al, 1990).

The findings of project Rainbow (Cook et al, 1999) suggest that visually impaired people can determine colour difference but there are areas in which difficulties exist, for example depending pathology (colour vision disorder). Related to the latter, different colours may have a similar luminance contrast, which means that for people who are unable to perceive differences in colour, the surfaces would appear to be identical. Therefore, there is a need to consider and adopt differences in luminance

[8] Luminance contrast is the difference in luminance form two adjacent surfaces. Luminance is the amount of reflected light from a colour, or is a measure of clarity; in the same illuminance or brightness, dark areas have a lower luminance than bright surfaces. Luminance is expressed in candela/m².

[9] Colour contrast is the difference in chromaticity of two adjacent surfaces (with the same luminance).

contrast in the environment, when considering adaptations for people with visual impairment. This trend is also detectable in the current guidelines. Three countries distinguish between luminance contrast and colour contrast (The Netherlands, the UK and Germany). Four countries only mention suitable colour contrasts (Belgium, Luxembourg, Sweden and Ireland) and one mentions 'the need for use of adequate contrasts', without further explanation (Portugal). Spain stipulates that *chromatic* contrast, based on the application of the equation of *luminance* of the clearest and the darkest colour, is recommended.
In our experience with guidelines -the latter confirms this argument- we consider the two different meanings of contrast as interchangeable. This can cause confusion among readers who have an interest in this topic (for example designers) and/or have no scientific background about it.

4.7.1. Luminance contrast

Table 1.8 explains how five countries deal with luminance contrast. All countries recognize luminance contrast as the most effective way to create contrast. Even more countries (see colour contrast) agree that black-white or white-black combinations lead to maximum contrast. Germany and Spain both use the Michelson formula to define visual contrast:

$$\text{Contrast} = \frac{L_{max} - L_{min}}{L_{max} + L_{min}}$$

Lmax = Luminance of the clearest colour

Lmin = Luminance of the darkest colour

(Contrast is usually expressed as a percentage; the ratio is multiplied by 100)

German guidelines recommend that adequate combinations have one or more of the following characteristics: a high luminance difference, an achromatic component, a combination of complementary colours and the use of red only as a dark component. Colour combinations can support the contrasting effect. People with normal vision require a less contrasting design, where a contrast of < 0.16 is small, < 0.64 is medium and ≥ 0.64 is high. Subjective assessment of different colour combinations with visually impaired people resulted in an optimum contrast above the normal contrast threshold, ≥ 0.83. Contrasting values can also be used as analogue percentages (0.83 becomes 83 %).

The German guidelines refer to the study ‘Kontrastoptimierung’ (Lindner et al, 1999), in which more information about the experiments (conducted in 231 partially sighted people) and the measurement of luminance (namely with a spectrophotometer) is found. Luminance is expressed in c/m² (candela per square metre). The values are placed into the formula and so the adequate contrast is calculated.

For Spain, the contrast is adequate for visually impaired people when the level of contrast between the shape and the background is at least 60%. Measuring levels of reflectance occurs with a spectrophotometer and the reading is based on a certified colour board used for colour prescription (Ral, Pantone, National Colour System (NCS)). No scientific research is appears to be available on this issue.

The Netherlands show ‘reflectance values’ of different materials and colours for normally sighted persons. Wijk (2008) states that the difference in reflectance value between the fore- and background of signs must be equal to or more than 0.30. The reflectance values of white and black are 0.85 and 0.04, respectively. Reflectance values of a few colours are given for orientation (see table 10). Yet, the reader does not know where this data comes from, or how to achieve it.

The UK mentions in the Sign Design Guide that contrast derives from the light reflectance factor of the colour. For people with visual impairments, the contrast between wall and sign panel should be 70 % (without further explanation). Further investigation revealed the extensive research of Project Rainbow in the UK, in conjunction with the University of Reading, the RNIB (Royal National Institute for the Blind) and Guide Dogs for the Blind. They examined how to contrast visually to adjacent critical surfaces, such as walls, ceilings, doors and floors in internal buildings, by selecting colours with a difference in Light Reflectance Value (LRV) of more than 30 percentage points. The method of calculating visual contrast is shown in the following formula, also called the Weber formula, which is also used in the US guidelines:

$$\text{Visual Contrast} = \frac{B1 - B2}{B1} \times 100$$

B1 = LRV of the lighter area

B2 = LRV of the darker area

Cook (2009)[10], one of the researchers of Project Rainbow, confirms the use of spectrophotometer equipment, as the best way to measure the reflectance value of a colour. This equipment can accurately measure the LRV of flat and curved items and both matt and gloss finishes can be evaluated. A range of internationally standardized light sources are built-in to the spectrophotometer allowing the influence of a wide range of light sources on the LRV of surfaces to be determined. Although the use of a hand held colour meter or luminance meter and a white, high reflectance standard surface, can give useful LRV of light reflectance measurements. The LRV's measured in this way depend on the ambient lighting and this should be quoted in relation to any measurement taken. This method does not allow measuring the influence of glossy or metallic surfaces, nor is it able to measure the LRV of curved surfaces. While the LRV's determined by this method are useful, they are not as accurate as those obtained by using the test method by the spectrophotometer.

Another method is that LRV can be approximated by reference to colour swatches or samples. They can be obtained from the manufacturer of the colour swatches or samples. In some cases (for example the colour notation that is used in the UK, see figure 7) the colour notation includes the LRV. The LRV measured in this way is also dependent on the ambient lighting. This approximate measurement method does not allow an accurate assessment of the influence of gloss on LRV. This very approximate method can be used for the initial selection of colours for design purposes and for preliminary site assessments, it is apparently not helpful in choosing definitive contrasting colours of signs and signage.

[10] Personal communication with Dr. Cook, University of Reading. Visual contrast and The Building Regulations 2000. Approved Document (AD(M))2004. Received at 10/08/2009.

Figure 1.8: Notation of the Colour Palette Notation System (ICI Paints)

The difference in LRV of more than 30 points became part of the UK legislation and is described in the approved Document Part M (2004) of the Building Regulations of the DDA[11]. Unfortunately, we do not know if the findings of Project Rainbow can be extrapolated to signs or signage. Is a difference in LRV of 30 points enough to enhance informational or directional signage in public buildings for people with low vision?

According to written comments of the California Council of the Blind (Lozano, 2009), the general consensus of professionals who work with people who are blind and visually impaired, including researchers, is that “to persons with reduced vision, the minimum contrast between dark and light LRV’s, for example characters with their background, should be 70 %”. Lozano states that this has been the minimum standard, according to the Weber formula, tested by both the Access Board prior to the adoption of the ADA[12] Accessibility Guidelines for Buildings and Facilities (ADAAG) in America and in the UK. As described before, in the UK, this is expressed by requiring a difference of 30 points between the two LRV’s. LRV’s range from 0 to 100, so a difference of 30 could represent a 70 percent contrast, for example:

LRV of the lighter colour = 45

LRV of the darker colour = 13.5

$$\text{Visual Contrast} = \frac{B1 - B2}{B1} \times 100 = 70\%$$

According to Bygg ikapp (Svensson, 2008), Scandinavian countries (Sweden, Denmark) and Canada recommend an adequate contrast between foreground and background of 0.70 according to NCS. No more information is given.

[11] Disability Discrimination Act (1995)
[12] Americans with Disability Act (1990)

The ISO Draft International Standard (DIS) 21542, which has been seen, recommends a difference on the LRV scale depending on the visual task: ≥ 30 points for large area surfaces, elements and components to facilitate orientation (according to the findings of Project Rainbow), ≥ 60 points to designate potential hazards and ≥ 60 points for text information. Using the Weber forumula, a difference in LRV of 60 points would mean:

$$(B1) = 70$$
$$(B2) = 10$$
$$\text{Visual Contrast} = \frac{B1 - B2}{B1} \times 100 = 86\%$$

Using the Michelson formula:

$$L_{max} = 70$$
$$L_{min} = 10$$
$$\text{Visual Contrast} = \frac{L_{max} - L_{min}}{L_{max} + L_{min}} \times 100 = 75\%$$

In the comments of the earlier version, Member body Sweden commented that 60 points is not feasible: because of weathering, discolouration etc. (especially outdoors) they say it is difficult to maintain this minimum. In Sweden, the value 40 is used. They state that the only way to achieve 60 will probably be to use quite dark material and white markings. They set for 40, although this was not found as such in Bygg Ikapp (Svensson, 2008). Other Swedish researches have not been found during the period of this study. In the Annex to ISO Draft International Standard (DIS) 21542, the recommended visual contrasts according to the different algorithms most commonly used throughout the world by reference to their luminance are given. Unfortunately, the last formula is not found in guidelines in this study.

Table 1.9 The recommended visual contrast according to the different algorithms most commonly used throughout the world by reference to their luminance.

Visual task	L1 – L2 x 100 L1 + L2	L1 – L2 x 100 L1	L1 – L2 x 100 05.(L1 + L2)
Small targets and warning function, potential hazards and text information	60	75	120
Large surfaces, elements and components for orientation	30	46	60

Jennes and Singer (2006) found in their study that the luminance contrast, provided by the detectable warning and the sidewalk, was an important factor for predicting the likelihood that a detectable warning would be seen. Where luminance contrast was 70 percent or greater (using the formula method), about 95 percent of participants were able to see the detectable warning from a certain distance. Detectable warnings that provided at least 60 percent contrast could be seen by about 92 percent of participants from the same certain distance. Dark warnings on a dark sidewalk were an exception. Although providing moderately high luminance contrast, these combinations were detected less often than would be predicted from their luminance contrast by a group of visually impaired people. Lozano (2009) explains this on grounds that the intervals along the dark to light continuum are not equal. A difference of 30 between two darker colours may be adequate, but a difference of 30 between two light colours does not provide enough contrast. On the other hand, the formula shows an inflated contrast between two dark colours. Lozano summarises by saying that: “there is a long-standing minimum percentage of contrast using the LRV that is recognized internationally and is used in various codes and standards, but we do not have a reliable way to determine the contrast, that is not skewed to favor two light colours, or two dark colours”.

As a result of this defect in the contrast, Jennes and Singer (2006) make the following recommendation: “if a contrast-based requirement for detectable warnings installations is used, the guidance shoud include a minimum luminance contrast and a minimum reflactance for the lighter of the two surfaces providing the contrast”. According to Lozano, the American National Standards Institute (ANSI) Committee has been considering such a standard. The figure that has received approval, is at least 45 LRV for the lighter of the two colours. For example:

LRV of the lightest colour = 45

- 30

= LRV of the darkest colour = 15

= 67% with Weber’s formula, 50% with Michelson formula.

In order to achieve 70% with Webers formula, one needs to go a few points higher with the lighter colour, or lower with the darker colour. At the same time, by requiring a fairly light colour, we are ensuring that we will not get a ‘false positive’ for two dark colours. So:

LRV of the lightest colour = 45

LRV of the darkest colour = 13.5

= 70% with Weber’s formula, 54% with Michelson’s formula

To achieve 60% with Michelson’s formula (Spain), we need to go more higher with the lighter colour:

LRV l = 60

LRV d = 15

= 60 %

The Michelson’s formula seems to be the most popular way to define contrast, at least in the scientific literature on this topic.

Table 1.10 Overview of the recommended luminance contrast in the EU countries

Country	Recommended luminance contrast	Remarks
DE	Luminance contrast (K) is measured by the Michelson formula. K ≥ 0.64: high contrast K ≥ 0.83: subjectively chosen as ‘optimal contrast’ by visually impaired. Luminance contrast depends on the surface of materials used (function of luminance, illuminance and reflectance of the illuminated surface) .	Optimal contrast: White – achromatic: K = ≥0.91 - ≤0.99 Black – achromatic: K = ≥0.97 - ≤0.99 (Negative) Yellow – achromatic: K = ≥0.89 - ≤0.99 Green – achromatic: K = ≥0.88 - ≤0.98 Blue – achromatic: K = ≥0.84 - ≤0.95 (Negative) Yellow – lila: K = ≥0.90 Yellow – blue: K = ≥0.87 White – lila: K = ≥0.92 White – blue: K = ≥0.98 Green – blue: K = ≥0.91 Yellow – red: K = ≥0.83 - white sign on dark background: board should be 25% larger.
NL	Difference in reflectance between fore- and background: ≥ 0,30. Difference in reflectance between signboard and background: ≥ 0,30. Note: these are values for normal	- For oriëntation, reflectance of: white = 0.85 black = 0.04 red (dark to light) = 0.10-0.35 yellow (dark to light) = 0.30-0.70 green (dark to light) = 0.05-0.60 blue (dark to light) = 0.05-0.50 - For orientation, reflectance of: white plaster = 0.70-0.80 concrete = 0.25-0.40

	sighted persons.	stone = 0.10-0.30 wood (dark to light) = 0.10-0.65
UK	Contrast derives from the light reflectance factor of the colours, not the difference between colours (e.g. light green against dark green). Contrast between wall and sign panel: 70 %.	- differences in contrast are essential between all elements of the sign: between background and the signboard, and between signboard and text or symbol on it. - No advice in contrast between signboard and text/symbol
ESP	contrast between fore- and background must be 60% conform to the Michelson formula.	Measuring level of reflectance occurs with photometer. The reading shall be based on a certified colour board used for colour prescription (RAL, Pantone, NCS)
SE	Adequate contrast between foreground and background of sign: 0.70 according NCS (National Colour System)	- According to this text, Canada and Denmark also use this recommendation.

4.7.2. Colour contrast

Eight countries provide recommendations about colour contrast. There is discussion about the use of psychological colours: Belgium, Sweden and the UK discourage it because of confusion with safety and emergency signs, the Netherlands, Germany and Ireland recommend it because of the global and clear awareness of the meaning. As shown in table 1.11, various colour combinations occur.

There seems to be discussion about the positive (DE) or negative (IRE, UK) contrast. In the UK and Irish guidelines, a negative contrast (white sign on a dark background) is more suitable for large text and causes less reflection or glare. With respect to glare, Legge noted that most of his low vision test subjects complained of glare when reading colour contrast text (and not when reading luminance contrast text). In their

past work, their experience was indeed that people with (or sometimes without) cloudy media read white-on-black faster than conventional black-on-white because of the extra light scattered from the page in the latter case. A similar explanation might account for depressed reading of equiluminant (but different colour) text. In that case, light can be scattered from both letters and background to dilute contrast.
According to German guidelines, with a negative contrast, the signboard should be 25% bigger to be readable. In Kontrastoptimierung (Behrens-Baumann et al, 1999), they concluded that, in subjective contrast assessment, partially sighted people prefer bright characters of signs on a dark background for non-coloured (black and white) and colour contrasts. Yellow was the preferred character colour. Rubin et al (1989) found that 5 out of 19 low vision subjects read white-on-black text faster than black-on-white at both high and low contrasts. In normal vision, the results were very similar for black-on-white and white-on-black. In four countries it is advised to contrast visually in every aspect of the signboard; adequate contrast between wall and signboard and signboard and text or symbol.

Table 1.11 Overview of the recommended colour contrast in the EU countries

Country	**Recommended colour contrast**	**Remarks**
BE	Suitable combinations: black-white[13], white-blue, black-yellow Non-suitable combinations: red-green, pure black-pure white (can cause dazzle or glare)	Limit colour use to psychological meaning (red, orange, yellow, green, blue)
NL	Suitable combinations: yellow-blue, light green-dark red, light green-black. Non-suitable combinations: red-green, black-red	
LUX	Maximal contrast: black-white or white-black	Attention for contrast between signboard and wall (e.g. white wall: dark frame around white background)

[13] First colour stands for text colour, second colour stands for background colour.

DE	Suitable combinations: white-black, black-green, white-blue, white-lilac, white-red, green-black, combinations of complementary colours (yellow-blue), combinations with achromatic colours (white-blue, white-lilac, green-black) or more: yellow-black, green-black, yellow-grey, green-grey, yellow-lilac Non-suitable combinations: white-yellow, black-blue, red-green	- Completion of luminance contrast - Red has signal meaning - Use red only as dark component of sign e.g. red-white, red-yellow (light component can be seen by a person with colour deficit)
SE	Use contrasting colours between text and signboard and signboard and background. Light text (rather cream than white) on dark background. For people with colour vision disorders: avoid combination between red and green, combinations with safety colours	If not possible, one should provide a contrasting board around signboard. - Too big contrast causes reflection or glare. Avoid colour combinations that are used for safety.
IRE	Black-white or white-black are good contrasting colours. Also: blue-cream text, black-yellow, cream-blue, cream-black	- Black- white: attention for reflection - for very large text: negative text (white-black)
UK	Best contrast = black-white or rather white-black, white-dark Red brick or dark stone: black/blue/green-white Light brick or light stone: white/yellow-black/dark Whitewashed wall: white/yellow-black/dark Green vegetation: black/blue/green-	- Black-white: attention for reflection - Attention for contrast between wall and signboard. If colour cannot be changed, a contrasting board (10% of width of signboard) should be provided. - Avoid colours that have a safety meaning

	white	- Avoid use of many colours
PRT		Use contrasting colours (text or symbol and background)

4.8. Lighting or illumination

Light is a very important element when providing adequate colour and luminance contrast to surfaces within buildings (Cook et al, 2004). The Netherlands suggest that illumination on signs should be more than or equal to 100 lux. This only seems to be confirmed in the guidelines of non-EU members Switzerland and America. Cook (2006) presented the illuminance recommended in BSI 2001 (Design of buildings and their approaches to meet the needs of disabled people, Code of practice, BSI, London). Corridors in buildings should have a standard maintained illuminance of 100 lux, while in entrances 200 lux should be attained.

Other countries suggest recommendations similar to each other, for example that the finish surfaces of the used materials should be matt to prevent reflections and glare (the UK, Ireland, Spain and Sweden), or that the presence of shadows must be avoided (this will significantly reduce contrast for the visually impaired). The orientation illumination must be evenly divided.

In every case, direct illumination should be avoided, for example by shielding the light from the viewers eyes. Self-illuminated signs are discouraged by the UK (Barker et al, 2000), although Cook et al (2005) verified the high visibility score given by 25 low vision participants to the LED (emergency) signs.

4.9. Positioning

For positioning of signs, five countries agreed with each other: BE, NL, IRE, the UK and Sweden recommended for a short reading distance, a positioning of the sign between (1.3) or 1.4 – 1.6 or (1.7) metres above the floor (see figure). Spain only mentions an upperlimit of the sign: maximum 1.75 metres above the floor. On the other hand, signs that have to be seen from a longer distance should be placed at a hight between 2 – 2.3 metres.

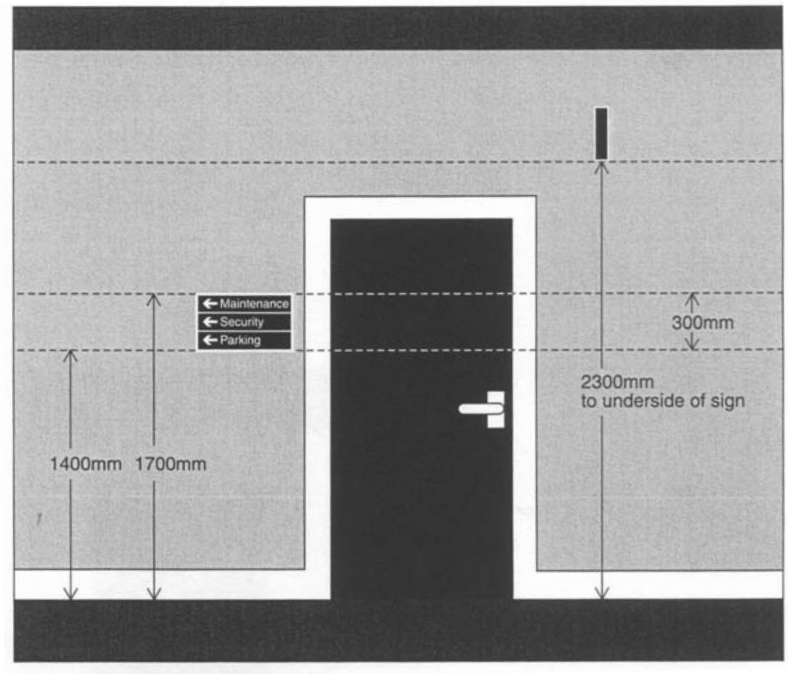


Figure 1.9: Position of signs (Barker et al, 2000)

It is also generally agreed that the location of signs should be uniformly located throughout the building and where they are clearly visible, in advance of the area for which they inform (see Figures 1.9, 1.10, and 1.11).

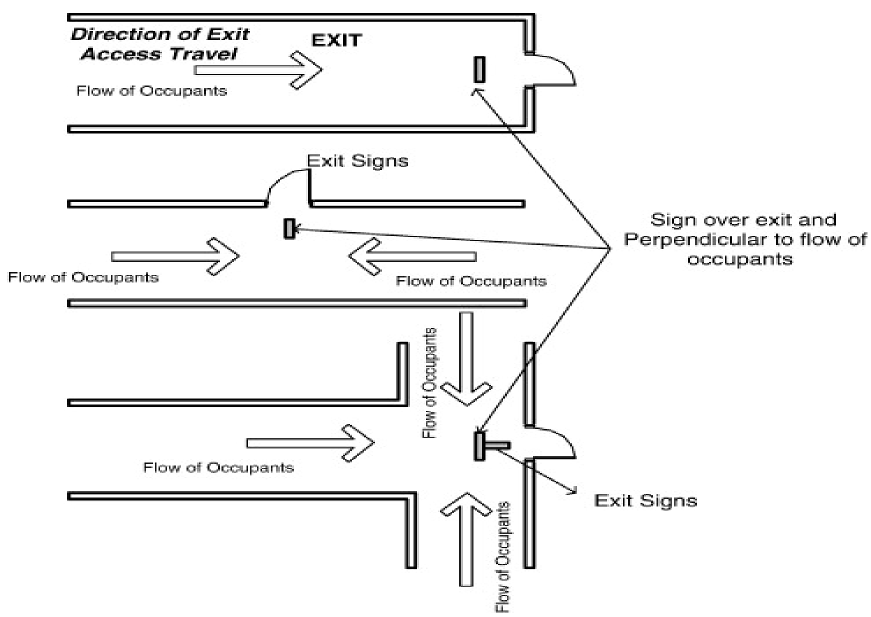


Figure 1.10: EXIT sign placement guidelines (Nassar et al, 2008)

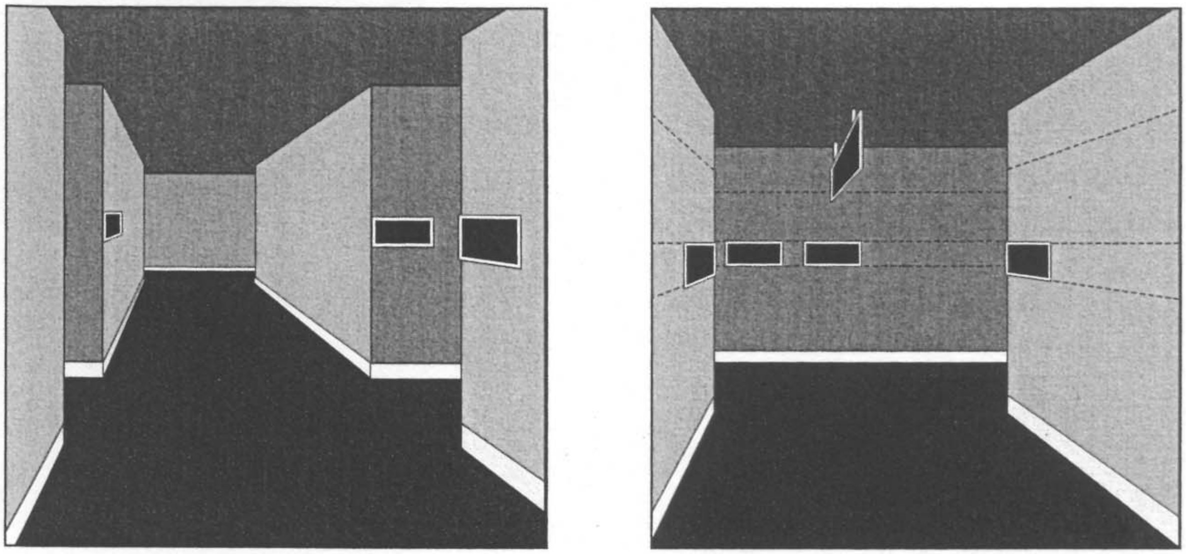


Figure 1.11: Consistency of signs (Barker et al, 2000)

Given that signs may require a significant period of time and may necessitate approaching in order to decrease reading distance, they should be located where users will not obstruct the passage of others. For example a toilet door sign should not be placed on the door, but on the side of the doorhandle and mounted on the wall. In this way, when the door is opened by someone leaving the toilet, they are less likely to bump into the person (wit low vision) inspecting the sign. The reader and the sign may never obstruct circulation paths. Spain mentions the need of an obstacle-free area in front of the sign (no glass etc). Belgium and the Netherlands say a sign viewed from below should be placed respectively at an angle of 10 and 15 degrees from the horizontal line of view.
Some authors state that an important or the first consideration in determining the effectiveness of signs is establishing the region from which the sign is visible, the so-called visibility catchment area (VCA) is not occluded to occupants (Xie et al., 2007; Nassar et al., 2008). According to Xie et al (2007), the VCA is dependent on the observation angle. The results of the experiment approximates a circle (the relationship between the observation angle and maximum distance from which the sign can be identified is non-linear, see figure 10). Nassar adds secondly that correct sign placement involves sign-specific variables such as using appropriate material, legible fonts and the type of sign. The study of Näsänen et al. (2004) showed that

contrast also has a strong effect on the speed of visual search. Note however that these findings are based upon experiments and reviews of people with normal vision.

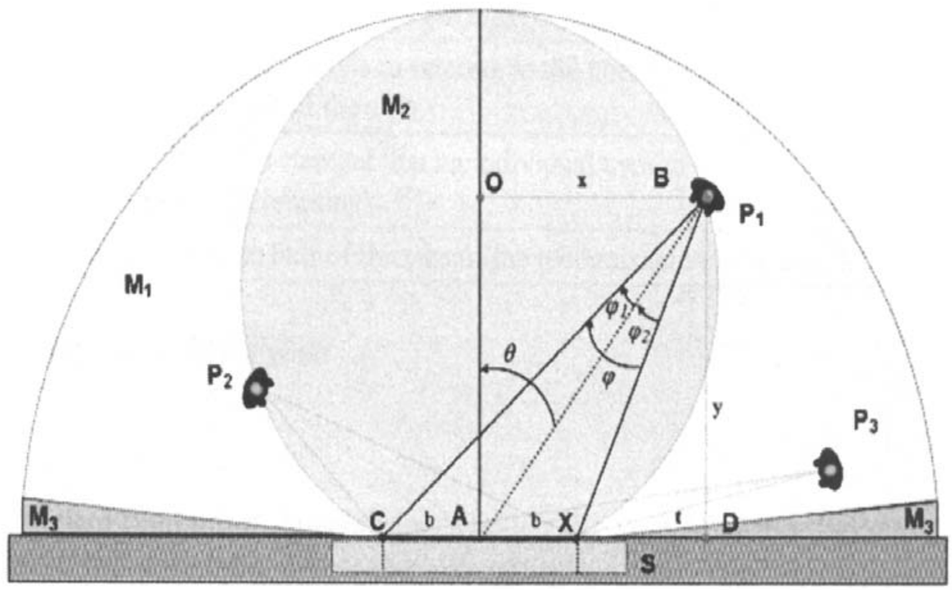


Figure 1.12: The geometric relationship between observer and sign, the VCA (Xie et al, 2007).

5. Conclusions of the literature overview and aims of the experimental studies

From this literature overview, it is clear that a large variation in guidelines for visual accessibility in the countries of the European Union exists. It is very likely that this variation stems from a lack of scientific research in many countries of the European Union. It also has to be noted that in some countries much more data are available due to a long experience and research in accessible building and standard regulations.

In general it is also notable that guidelines of several countries do not contain dimensional requirements, but only give advice on which topic should be taken into account. Other countries provide detailed regulations with specific dimensional requirements. A general an major shortcoming in a significant proportion of guidelines as well as experimental studies is that guidelines are not systematically coupled to a specific population, i.e. to the specific visual characteristics of a group of intended users.

This study attempts to make a step forward towards standardization of visual accessibility guidelines, thereby focusing on two important aspects: size and contrast. With respect to the large variety in recommended character size (see Table 1.6 for an overview), a fourfold difference between the lowest (1.5% of reading distance) and the highest (6%) reference value was observed. Related to the issue mentioned above, these guidelines should be linked to visual characteristics of a group of users. From this point of view, the term ‘critical reading distance’ seems to be more appropriate in this context.

With respect to contrast, it is clear that luminance contrast is extremely important for people with low vision to distinguish text or symbols from its background. But from the previous shown guidelines it is also clear that misunderstandings can easily arise, because there appear to be different approaches of determining visual contrast, which creates confusion when trying to compare data to each other. In some guidelines, contrast is calculated by reading colour samples where LRV is given and the minimum difference in both LRV’s are expressed in points (Sweden, the Netherlands, the approved document Part M of the UK). In other guidelines, determination of visual contrast by different algorithms are used where measuring the

LRV with special equipment is necessary (Spain, Germany, the Sign Design Guide of the UK). Some guidelines are based on scientific research with people with visual impairment, others are not. It is not always mentioned as such. Some researchers did not aim the same (for example contrast of signs and signage versus contrast between large area surfaces, elements and components to facilitate orientation).

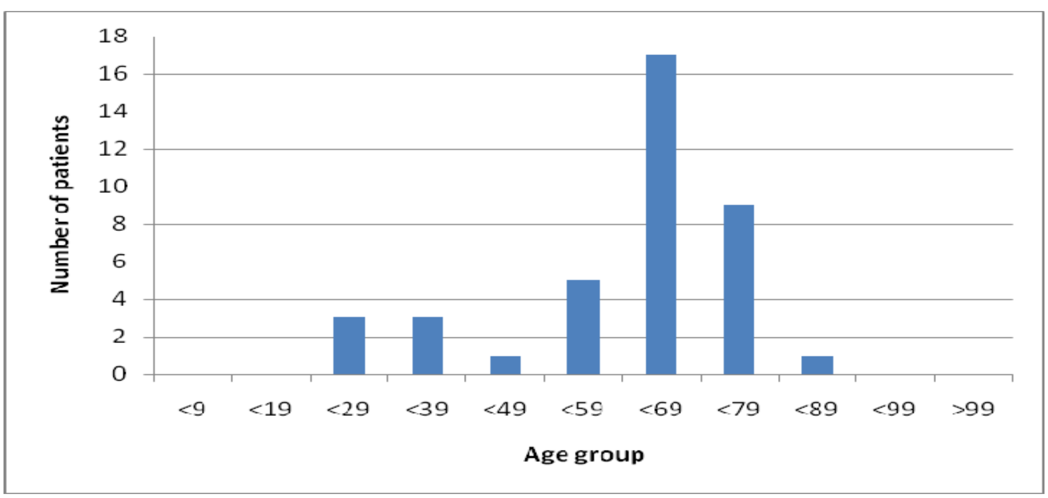
The aim of the experiments reported hereafter is to provide a scientific basis for the development of guidelines for character size and foreground/background contrast. More specifically, the following aims and hypotheses are put forward.

1. The minimal character height adequate for a range of visually impaired test subjects, expressed at a percentage of reading distance, is to be put forward. It is generally expected that reading/recognition performance will linearly increase with increasing character size, although very large characters might be problematic for people with a restricted visual field that would obstruct the overview of the picture or word presented. In general character sizes in the range of the existing guidelines will be explored (between 1% and 9% of critical reading distance), with one of the scarce scientifically supported guidelines being situated in the middle of this continuum (5% reading distance, Den Brinker et al, 2008).
2. The proposed contrast level for most low vision participants to recognize signalization. Literature overview allows us to predict a (linear?) increase in reading/recognition performance with increasing contrast.
3. The interaction between size and contrast is an important issue with respect to the practical implications. In situations that do not allow the use of a character of a certain size, to what extent could this be compensated by using a maximal contrast in the signalization? In addition, it is predicted that contrast will not equally affect performance in the whole range of character sizes used in the experiments.
4. These aspects will be studied in a pure recognition task (in which the location of the sign is does not vary), and in a localization/recognition task (in which the sign must be 'found' in a complex background before the participant is able to recognize it). This relates to the issue of 'findability' and readability as two consecutive processes (Den Brinker, personal communication March 2010).

PART TWO: EXPERIMENTAL STUDIES

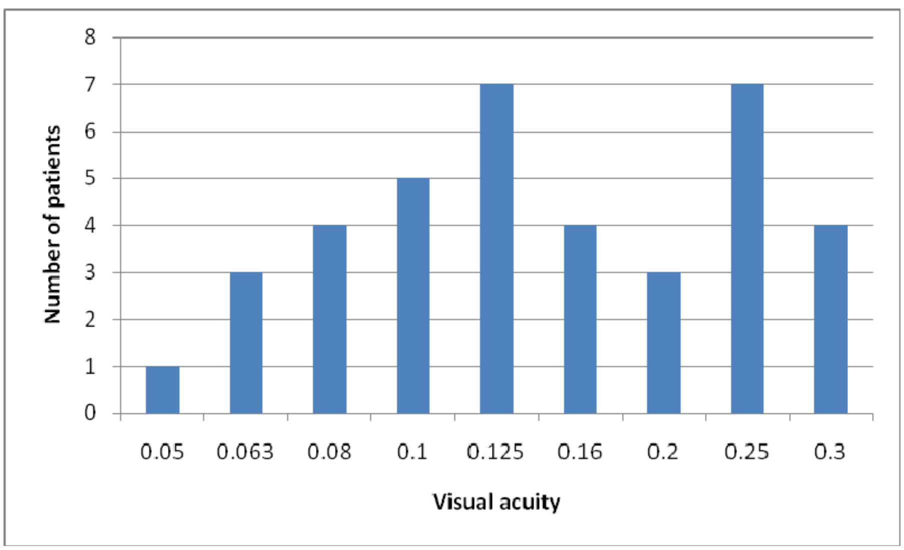
1. Participants

Fifty volunteers agreed to participate in the two experiments. However, due to the unusually bad weather and the accompanying travel difficulties in the period of the experiments, eight of them did not take part in the study. Two of the 42 remaining participants had normal vision and served as control subjects. The group of 40 patients consisted of 18 males and 22 females. Inclusion criteria for the patient group were in agreement with the definition of low vision of the WHO (see part one). Most participants were recruited from the database of the Centre for Visual Rehabilitation of the University Hospital Ghent. Some of the patients, mostly from the oldest age groups, were recruited from the ophthalmology clinic. Before the first contact, they were selected from these databases in order to obtain a patient sample that was representative for the European low vision population. To this end, the age of and the specific visual condition of the patient were taken into account. All participants are recently seen by an ophthalmologist. Figure 2.1 shows the age range of the participants. Although in the global population the prevalence of low vision increases with age, it was not possible to find enough older patients that were willing or able to make the travel to the hospital for the experiments. In addition, the older patients from the Rehabilitation Centre often exhibit serious visual loss that prevented them from participating. Nevertheless, the participants were fairly representative for the European low vision population.



Figuur 2.1: Age range of the participants (<29 means between 20 and 29 yrs of age)

All patients suffered from a certain degree of visual acuity loss. Figure 2.2 gives an overview of the visual acuity of the patients in both experiments. Participants are divided into four groups, as is expressed in Figure 2.3. Group one is the group of visual acuity loss with normal to almost-normal visual fields. This group contains people with a diagnosis of maculopathy and chorioretinitis. Group two consists of pathologies featured by a central scotoma, like Stargardt disease, myope choroïdose, Leber hereditary optic neuropathy or macular atrophy pathologies. Participants of group three exhibited a restriction of the visual field due to diabetic rethinopathy, retinitis pigmentosa and neurofibromatosis. Finally, we defined group four as a mix of a restriction of the visual field in the better eye and a scotoma in the worse eye, partial restricted fields, etc. In this group pathologies like glaucoma, diabetic retinopathy, achromatopsy, were noticed. For the purpose of analysis in these experiments, two groups were created, one group with patients suffering from a decreased visual acuity without severe visual field reduction, and a group with a decrease in visual acuity as well as in visual field (see 3.2.).



Figuur 2.2: Visual acuity range of the patients.

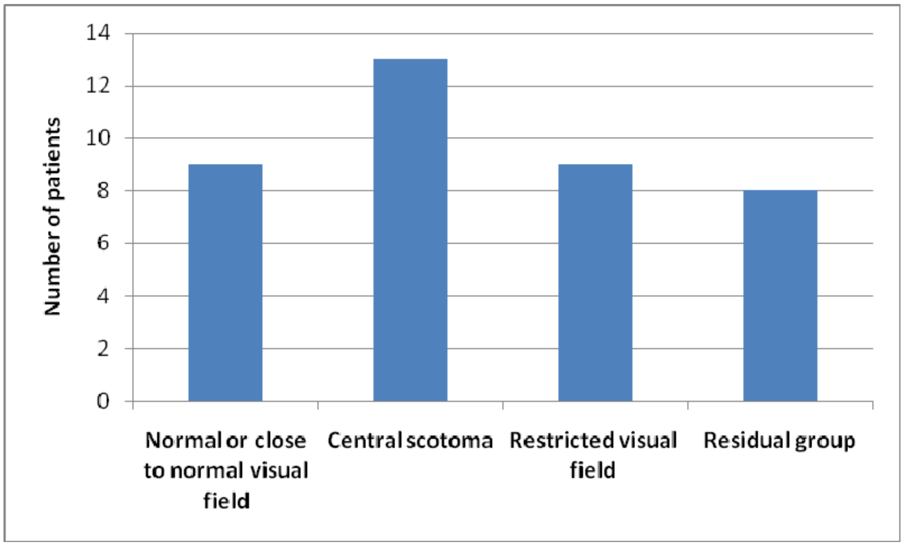


Figure 2.3: Subdivision of patients in the experiments, based upon the nature of the loss in visual function.

2. Clinical function tests

Participants and volunteers (normal sighted control group) were subjected to verification of their visual performance by a number of clinical functional tests before the actual experiments. The following tests were used: the visual acuity for distance by ETDRS (International Council of ophthalmology, 2002), the visual field with the Goldmann perimeter, and contrast sensitivity using the VISTECH-test (Uvijls et al, 2007).

2.1. Distance visual acuity measurement

ETDRS acuity testing has become the worldwide standard for visual acuity (VA) testing (Laidlaw et al, 2001). ETDRS stands for Early Treatment Diabetic Retinopathy Study. The ETDRS testing device has patented self-calibrated test lighting. The ETDRS were displayed in the standard light box. The ETDRS allows testing up to 6/60 (1/10 or 20/200) ETDRS acuity at a test distance of 4 metres and up to 3/60 (1/20 or 20/400) at 2 metres. All participants wore their habitual spectacle correction. All charts were read monocular from a distance of 4 metres unless the subject misnamed several letters on the top line of the given chart. In this case, the subject was advanced to 2 metres distance from the display. The end point for each chart was defined as 3 or more letters of an entire line being misread. In order to minimize potential learning effects, different charts were used for the right and left eye respectively.

2.2. Contrast sensitivity measurement

Vistech measures the participant's contrast sensitivity to a particular object size. The low frequencies test sensitivity to large objects while the high frequencies measure sensitivity to small objects. The test occurred in a darkened room with an illumination of 315 lux in the immediate surroundings of the chart. The Vistech test plate used in the University Hospital Ghent consists of grids with vertical patterns in three directions: 105° (shifted to the left), 90° (vertical), and 75° (shifted to the right). The average luminance level of the patterns is 70cd/m², while the background of the white board on which the sinusoidal grids are made a luminance level of 150cd/m². Spatial frequency diminishes progressively with each succeeding pattern. The participant reported the lowest contrast grid visible in each grouping and describes the orientation of the pattern. This is the score of the contrast threshold for that spatial frequency. These scores can be directly plotted in a curve. All participants also wore their habitual spectacle correction and were tested binocularly from a 3 meters distance and monocularly at a distance of 1 meter.

2.3. Visual field measurement

Visual field measured with the Goldmann perimeter measures the complete visual field. To that aim, it is necessary to use various targets (Index V4, I4 and I2), so that a detailed evaluation of the state of the visual field can be made. Our low vision participants had different eye conditions which can lead to, on one hand, changes in the central visual field and on the other hand, changes in peripheral vision. The exact limits of the scotomas or the constricted visual field were determined. Examination occurred in a completely dark room. The non-tested eye was covered, the tested eye was provided with a reading addition if necessary (adapted to the 30 centimetres test distance and the age of the participant).

3. Experiment 1

3.1. Task and procedure

In the first experiment participants were asked to recognize short words (maximum 6 characters) and icons or symbols that are commonly used in public spaces. Words were in Flemish language, with some of these in English if they are commonly used as such in Flanders. The words and the icons are presented in Figures 2.4, 2.5, 2.6, and 2.7. In line with the recent study of Arditi et al (2007), we choose for uppercase Arial letters, with a normal (standard for Arial) letterspacing. Every word is surrounded by a small board in the opposite contrast. A random mixture of black characters on a white background, and white characters on a black background was used. The icons were chosen on the basis of their frequency in public spaces and so that the content of the icon was comparable in size to the letter and word stimuli used. Very complex signs were not included in this experiment. The icons were presented in the center of a dark black background on a 17 inch laptop screen and projected on a large screen (2,7 by 3,0m). The experiment took place in a large room (7 by 18 m). In order to control the lighting conditions, all windows were covered and artificial light was used. In order to maintain a certain contrast on the screen, an illumination of 50 lux was used, in the overall space of the room.

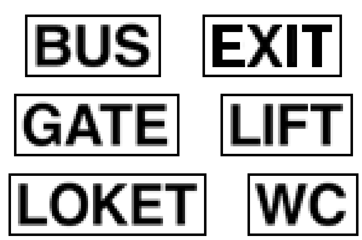


Figure 2.4. Words in black characters on white background.

Figure 2.5. Words in white characters on a black background.

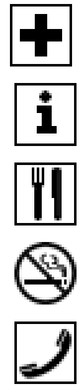


Figure 2.6. Icons in black characters on a white background.

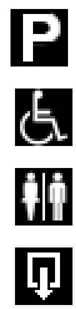
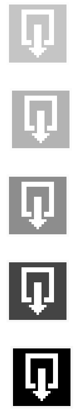


Figure 2.7. Icons in white characters on a black background.

Stimuli could be presented 5 sizes (height of the icon/word) and 5 contrast intensities. Projected sizes were 4.5, 13.5, 22.5, 31.5, and 40.5 cm, corresponding to 1, 3, 5, 7, and 9% of the standard reading distance of 4,5 m from the screen. At this distance, the investigated VF is 16°. Contrast intensities were determined as follows. The contrast difference between white and pure black was set at 100%, and in a pilot study values of 20, 40, 60, 80 and 100% were selected. The equal distance between these contrast intensities are however not perceived as equal by the human visual system. Therefore, these values were visually modified and set at 28, 36, 53, 81, and 100% of maximal contrast on the black-white axis. An example of the five contrast intensities is presented in Figure 2.8. Using the Weber formula for the determination of the exact contrast values, the effective values were systematically lower than was digitally aimed at: 14%, 21%, 33%, 60%, and 76% respectively. From here on, these values will be used systematically.



14%

21%

36%

60%

76%

Figure 2.8. Contrast intensities used in Experiment 1.

All stimuli were integrated in a custom-written program with Inquisit software. The five sizes and the five contrast intensities resulted in 25 size-contrast combinations that were randomly used in the experiment, with each combination being presented 4 or 5 times. Participants sat on a chair with a custom-made device with five integrated press-buttons on a table in front of them. The device, that included a timer with an accuracy of 0.001 sec, was designed as such that the buttons were maximally visible (black on a white background) and large enough (3 cm diameter and 6 mm of height) to be haptically located if necessary. This device was connected to the laptop (see Figure 2.9).

Figure 2.9. Overview of the experimental set-up. The participant uses the button box to indicate that he/she has located and identified the sign (picture from Exp 2).

On entrance in the experimental room, participants were asked if they were well informed on the aims of the study. If so, the experimental procedure was explained to them. Before the actual experiment began, a series of 10 familiarization trials was presented. On appearance of a stimulus, participants had to identify it by pressing the central button on the electronic device, and verbally reading the word or describing what icon was presented. They were instructed to try to respond as fast as possible. The experimenter used a score sheet to document whether the word or icon was correctly identified. After each trial, participants indicated to what extent they found it difficult to identify the stimulus by giving a score of 1 (extremely difficult) to 4 (very easy). There was no time limit between the presentation of the stimulus and the participant's response (i.e. when the button was pressed). However, the post-trial interval (time between the button response and the presentation of the next stimulus) was set at 8 seconds, during which the experimenter evaluated the participant's answer and the difficulty score on the scale from 1 to 4. The set of 10 familiarization trials was repeated if necessary, i.e. when the participant was not comfortable with the order of responding as follows: 1) Press the button as soon as you are able to identify the stimulus, 2) Describe the icon or read the word presented aloud. After the familiarization procedure, three blocks of 40 trials in which the 25 size-contrast combinations were randomly integrated, were presented to the participants, resulting in 120 trials. A short rest of 5 minutes between blocks was provided.

3.2. Dependent variables and statistical analysis

Data were collected in an Excel sheet to which the verbal responses were added after the experiment. The following dependent variables were then retained for further analysis:

a) <u>Number of correct/wrong/I don't know answers</u> per size-contrast combination (in %)

b) <u>Response time</u>, defined as the time between presentation of a stimulus and the participant pressing the button, expressed in milliseconds.

In a first analysis, these variables were then submitted to a 5 (stimulus size: 1, 3, 5, 7, or 9% of reading distance) x 5 (contrast intensities) Repeated Measures Analysis of Variance (ANOVA) with Green-Geisser correction in case of violation of the sphericity principle. Effect size was reported by means of the eta squared (η^2)

procedure. Least Significant Difference procedure was used as post hoc test. This analysis allowed to investigate how the identification of a given stimulus is affected by size and contrast in the general low vision population, without differentiation based upon the exact nature of the low vision condition. In a second analysis, the patient group was divided into two groups, one with mainly a visual acuity loss without (or very limited) loss of visual field (Limited Visual Acuity (LVA) ; n = 29), and a group with an additional significant restriction in visual field (Limited Visual Field (LVF; n = 10). Data of the control subjects (n = 2) were not used for statistical purposes, but served as a reference value.

3.3. Results Experiment 1

3.3.1. Reference values (control subjects)

3.3.1.1. Response accuracy

Response accuracy of the control subjects was perfect (100% correct) in all trials, irrespective of the size and the contrast of the stimuli presented.

3.3.1.2. Response time

Even in subjects with normal vision, response time tended to be affected by the size and the contrast of the symbols. Participants responded tended to respond slower (822 msec on average) when the smallest symbols were presented in comparison to the other four conditions (all close to 750 msec in the four largest conditions 3%: 748 msec; 5%: 785 msec; 7%: 733 msec; 9%: 739 msec). No clear effect of contrast was observed with average values of 746 (14%), 813 (21%), 770 (33%), 718 (60%), and 780 (76%) msec. From Figure 2.10 it is clear that the effect of faster responses with larger stimuli tends to fade out as the contrast of the stimuli increases.

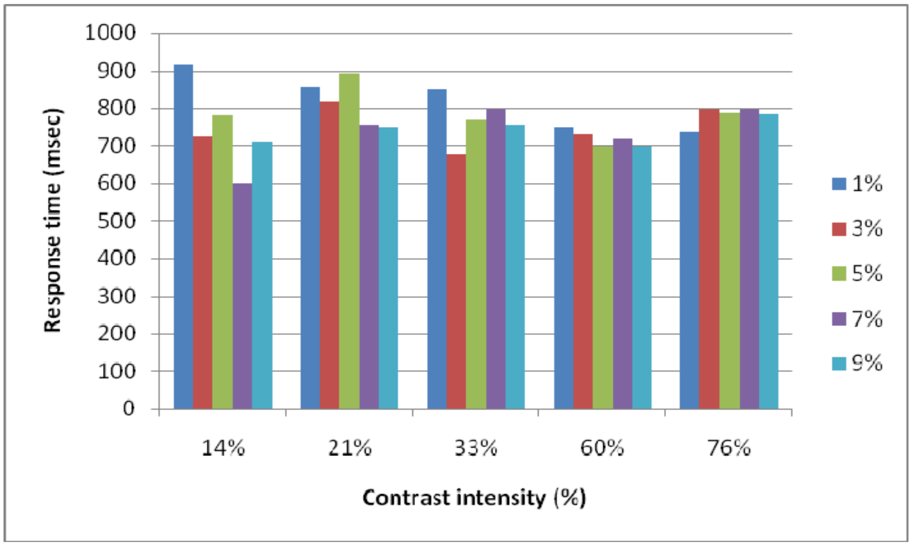


Figure 2.10. Responses times of the control participants in Experiment 1. Symbol size (in % reading distance) is indicated in the legend on the right axis.

3.3.2. Overall low vision group

3.3.2.1. Response accuracy

Preliminary analysis of the data indicated that participants only rarely made mistakes, but rather used the ‘I don’t know’ option in the verbal reports. Less than 2% of all trials resulted in a wrong answer, which insufficient to treat these trials as a separate category in statistical analyses. Therefore, wrong answers were taken together with ‘I don’t know’ responses. Given that the sum of this new category, and the correct answers by definition results in a sum of 100%, it was chosen to use the percentage of correct answers for further analysis.

Increasing stimulus size resulted in better response accuracy ($F_{4,156} = 141{,}472$, $p < .001$, $\eta^2 = .78$), with significantly better accuracy with each increase in stimulus size, except for the transition from S4 to S5 which did not result in a more accurate response. In the 1% condition, participants recognized the stimulus in 22.9% of the trials, a number that rapidly increased to 73.6% in the 3% condition, while performance was close to maximum in the three remaining conditions (5%: 93.1%; 7%: 95.5%; 9%: 96.7%). This main effect of stimulus size is shown in Figure 2.11.

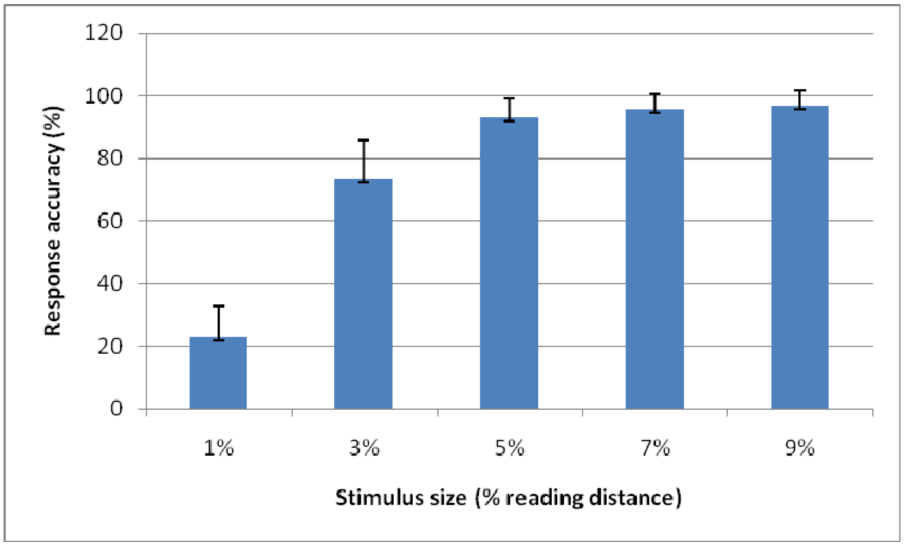


Figure 2.11. Effect of stimulus size on response accuracy in low vision patients. Means and standard deviations.

A similar effect of contrast on response accuracy was noted ($F_{4,156} = 26{,}074$, $p < .001$, $\eta^2 = .40$), with better scores with each increase in contrast, except for 60% and 76% that were not different from each other. In the lowest contrast condition response accuracy was still 70.7%, a figure that gradually raised in the other four conditions (74.0% - 76.4% - 79.7% - 80.8%). This is shown in Figure 2.12.

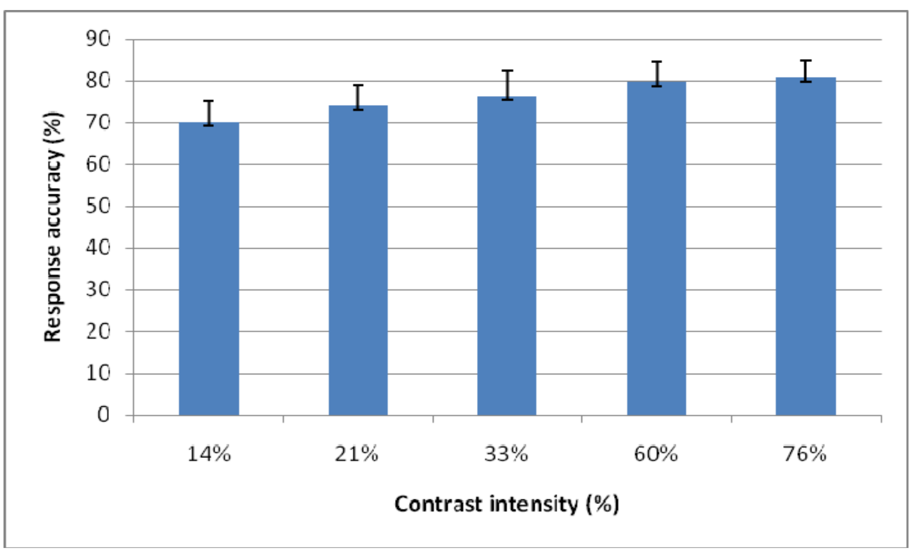


Figure 2.12. Effect of stimulus contrast on response accuracy in low vision patients. Means and standard deviations.

The significant interaction effect ($F_{16,624} = 6.800$, $p < .001$, $\eta^2 = .15$) revealed that the effect of contrast was strongly dependent on the size of the stimulus presented. Contrast led to a large increase in response accuracy in the conditions with the smallest stimulus sizes (1% and 3%; $F_{4,156} = 20,180$, $p < .001$, $\eta^2 = .34$ and $F_{4,156} = 13.346$, $p < .001$, $\eta^2 = .26$, respectively). In the 1% condition, contrasts 14% and 21% led to similar response accuracy, as did contrasts 60% and 76% compared to each other. All other pairwise comparisons showed significant differences between contrast conditions. In the 9% size condition a significant effect of contrast was found also, although not as pronounced as in the smallest size conditions ($F_{4,156} = 3.364$, $p < .05$, $\eta^2 = .08$).

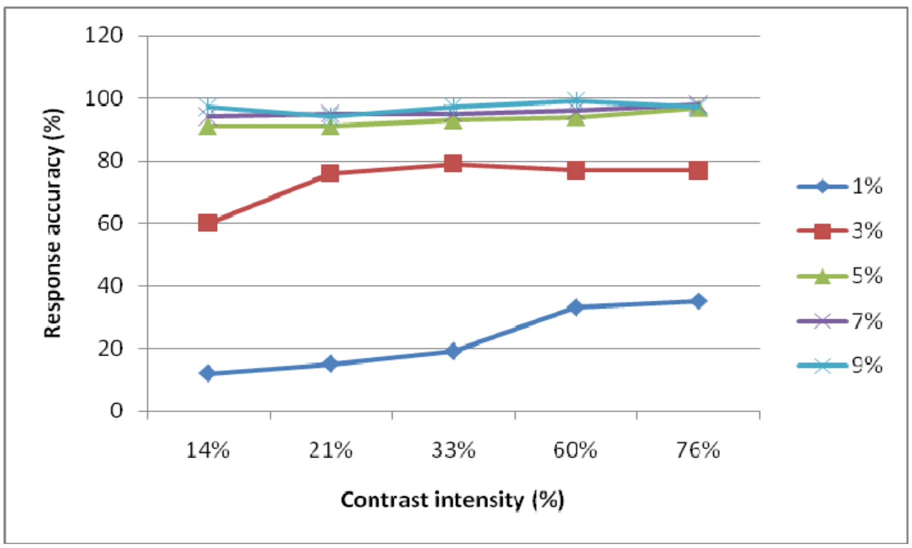


Figure 2.13. The size by contrast interaction effect on the response accuracy in low vision patients. Symbol size (in % reading distance) is indicated in the legend on the right axis.

3.3.2.2. *Response time*

Increasing the size of the stimuli resulted in shorter response times ($F_{4,156} = 8.563$, $p < .001$, $\eta^2 = .18$), with the response times ranging from 2603 msec for the smallest stimuli (1%) to 2033 for the largest ones. All conditions differed significantly from each other, except for the pairwise comparisons between 1%-3%, 1%-5%, and 7%-9%.

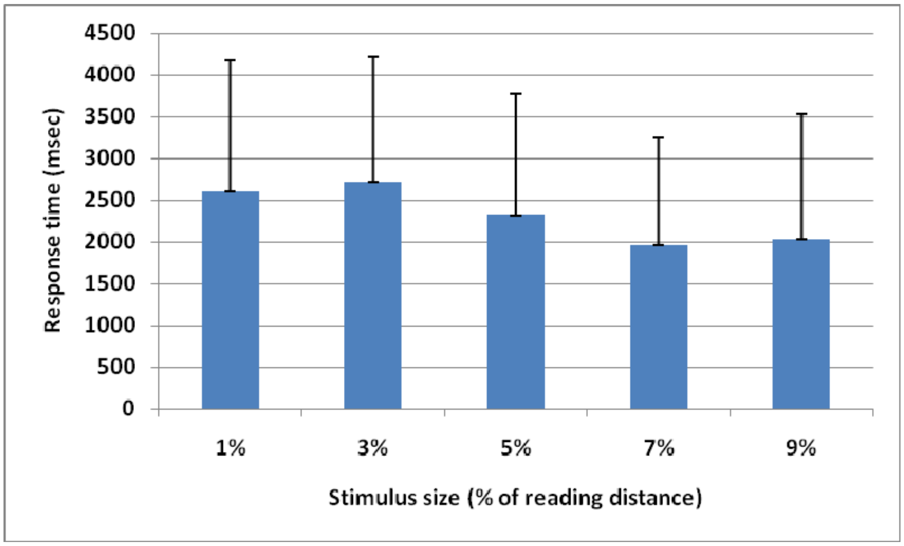


Figure 2.14. The effect of stimulus size on response time in low vision patients. Means and Standard Deviations. Note that response time is sometimes shorter in the smallest size condition due to the increased number of ‘I don’t know’ responses.

Better contrast led to shorter response times ($F_{4,156} = 6.755$, $p < .001$, $\eta^2 = .15$), ranging from 2482 msec on average in the stimuli with the lowest contrast to 2118 msec when the highest contrast was presented. Response time differed significantly between all conditions, except for the pairwise comparisons between 14%-21%, 14%-33%, and 21%-33%.

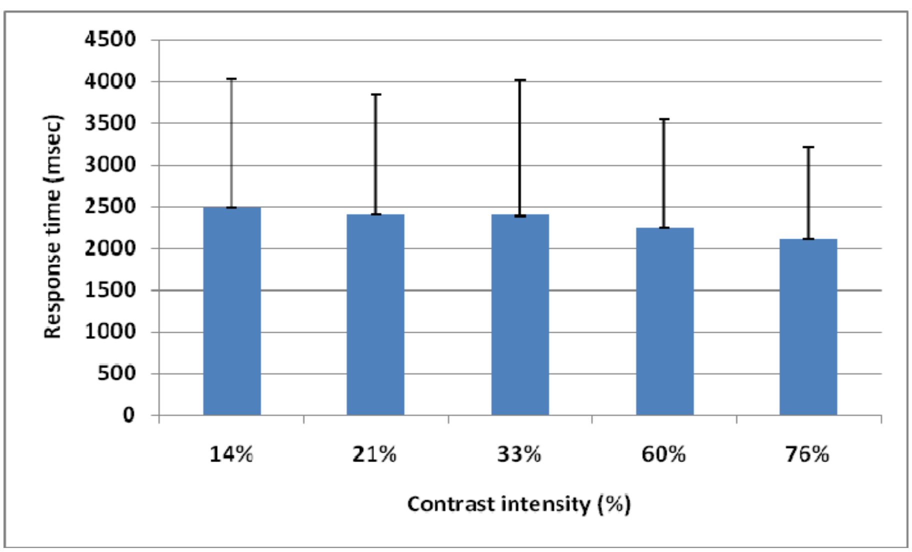


Figure 2.15. Decrease of response time with increasing contrast in low vision patients. Means and Standard Deviations.

The significant interaction effect ($F_{16,624} = 3.093$, $p < .001$, $\eta^2 = .07$) revealed that the effect of contrast depended on the size of the stimuli presented. In the 1% condition, contrast did not affect response time ($F < 1.0$, ns). In the other four conditions, a better contrast resulted in a shorter response time, although this effect became smaller with increasing stimulus size. In conditions 3% and 5% ($F_{4, 156} = 5.901$, $p < .001$, $\eta^2 = .13$ and $F_{4, 156} = 5.151$, $p < .001$, $\eta^2 = .13$), response time in the 14% contrast condition was different from the three highest contrast conditions, while this pattern was much less pronounced in the 7% and 9% condition ($F_{4, 156} = 5.435$, $p < .001$, $\eta^2 = .12$ and $F_{4, 156} = 3.121$, $p < .05$, $\eta^2 = .07$).

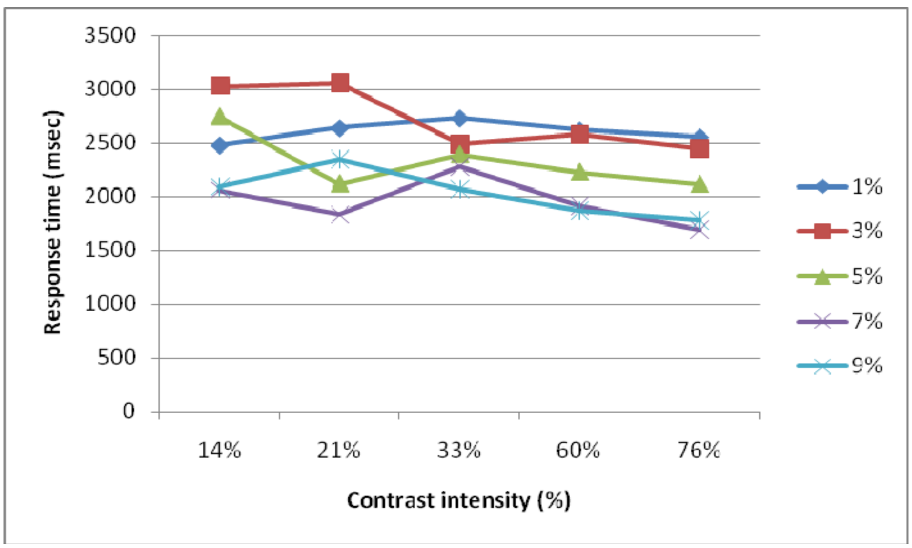


Figure 2.16. The size by contrast interaction on Response time in low vision patients. Symbol size (in % reading distance) is indicated in the legend on the right axis. Note that performance is sometimes better in het smaller size conditions, due to an increased number of 'I don't know' answers (see discussion).

3.3.3. LVA and LVF group

3.3.3.1. Response accuracy

The subgroup with the restricted visual acuity and the subgroup with a limited visual field had a similar overall response accuracy (LVA: 77.6% vs. 77.3% for the LVF group; $F_{1,36} = .002$, ns). The same main effects and interactions as in the global patient group analyses were found here. No additional interactions with the type of low vision occurred.

3.3.3.2. Response time

The 5 x 5 repeated measures ANOVA with the two types of low vision as between-groups factor resulted in the same main effects and interactions as the previous analysis, but the type of low vision interacted with the size ($F_{4,144} = 2.654$, $p < .05$, $\eta^2 = .07$). Figure 2.17 shows that the expected linear decrease in response time with increasing size was only visible in the LVA group, with their response time decreasing more or less linearly from 2654 msec to 1844 msec. Post hoc analyses showed that patient responded faster in the 1%-3%-5% condition as compared to the 7%-9% conditions. The LVF group showed no faster response as a function of increasing stimulus size (2594 msec and 2680 msec for the smallest and largest stimulus size, respectively), but the response time was longest in the 3% condition (3604 msec). Post hoc analyses revealed that the response time was longest in the 3% condition as compared to all other conditions, while condition 5% and 7% did not differ from each other either. There was no overall effect of type of low vision on response time ($F_{1,36} = .2.350$, ns), although the LVA tended to respond faster (2211 msec on average) compared to the LVF group (2826 msec on average).

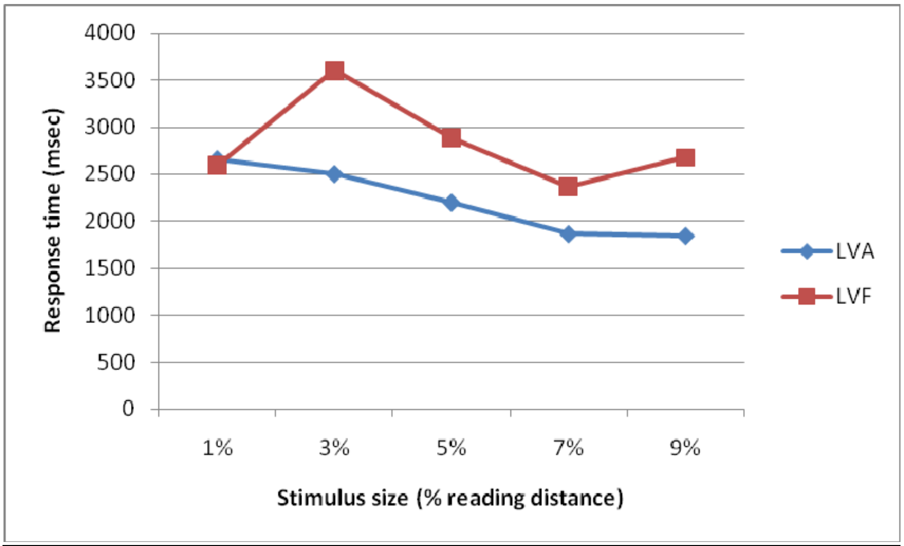


Figure 2.17. Size effect on response time in the two patient groups. LVA = Limited Visual Acuity; LVF = additional Limited Visual Field.

3.4. Discussion Experiment 1

Patients with low vision took about three times longer than control participants to make their final decision in each trial, independent of the correctness of that decision. In addition, people with low vision were unable to correctly identify the icon or word in one out of four trials on average, which is in contrast with the 100% accuracy in response of the control subjects.

More pertinent to the research aims of this project was that size as well as contrast of the stimuli affected response accuracy and response time. With respect to size, it was found that icons, words or symbols smaller than 5% of reading distance lead to an unacceptable response accuracy in people with low vision, which is in line with the proposal of Den Brinker et al (2008). This would mean that in real life, people with low vision would either go the wrong way, or be lost without help from other persons. Response time was also affected by stimulus size, which parallells the tendency observed in controls too. The effect of size on response time is not a linear decrease with increasing stimulus size, as one could have expected. Participants did not respond faster in the 3% condition compared to the 1%. It appears that in the latter condition, stimuli were way too small to be recognized, resulting in participants not attempting to identify stimuli of that size. As such, they responded relatively quickly, in most cases with ‘I don’t know’.

The effect of contrast was not of the same magnitude as the effect of size, at least for the contrast ranges used in this experiment. Even in the lowest contrast condition, a accuracy of more than 70% was attained. It was clear from the interaction effects that contrast only matters when the size of the stimulus comes near or is below the value of 5% of the reading distance, as is shown in Figure 2.13. A similar result was found with respect to response speed. Although the ability of correctly identifying words and icons is of crucial importance for people with low vision, a short response time is more a matter of comfort.

The comparison between the LVF and LVA patient group led to some remarkable results. At first glance, both groups score almost identically on the recognition of signs in terms of correct/wrong. However, it is clear from figure 2.17 that the LVF group has more problems, resulting in an average response time that was longer (although not significantly) compared to the LVA group. Potential problems with increasing sign sizes for people with a restricted visual field are also apparent from this figure. While the LVA group continues to respond faster with increasing stimulus size, the LVF group again tends to respond slower once the stimulus size exceeds the 7% size. It is likely due to the fact that LVF patients are not able to get an overview of the whole sign without moving their eyes or head due to their restricted visual field.

Although the control group was too small to submit the data to statistical analysis, it seems from figure 2.10 that the effect of increasing contrast leading to shorter response times only holds for the 1% of critical reading distance condition. So the effects of size and contrast, and especially the interaction between these factors, are not the same in people with low vision as and persons with normal vision. Proposing guidelines for low vision groups is by consequence not straightforward: it is not, for example, a mere increase of the size of a sign, but other factors (probably also other factors but contrast) should also be taken into account.

In this Experiment, the location of the stimulus was always the same and no visual search for the stimulus was necessary. However, in real life the exact location of a specific piece of information is often not known in advance. In general people must first be able to find the location of a sign, before trying to recognize it, a process for which it often necessary to approach the sign. It is expected that response times will be much longer when the process of recognition is preceded by a searching process, and its needs to be shown whether the effect of size and contrast within a given sign are the same in such situations. Therefore, in the second experiment, participants had to search for a given symbol or word.

4. Experiment 2

4.1. Task and procedure

The same stimuli as in Experiment 1 were used, this time embedded in a realistic environment. To this end, a picture of the Saint-Louis railway station (USA) was used as background in all trials in experiment 2. Stimuli of all five available contrast intensities and the three smallest sizes (1, 3, and 5%) were embedded in the picture which remained the same projected size at 3.2 m from the patient, resulting in the screen covering about 21° of the visual field. For the two largest sizes (7% and 9%), embedding them in the same picture resulted in a very artificial look. Therefore the two largest sizes were presented by using the background with the 3% and 5% embedded pictures and decreasing the viewing distance of the participants to 1.5 m so that these icons were effectively at 7% and 9% of viewing distance without harming the natural look of the overall picture. In this condition, the total scene projected on the screen covered about 40° of the visual field. Lovie-Kitchin & Whittaker (1998) showed that both magnification techniques do not affect reading performance in a different way in adults with low vision. In each picture, 9 randomly chosen icons, each of the same size and contrast intensity, were embedded. Order of presentation was randomized (see however under procedure). In Figure 2.18 an example of the embedded-icons-picture is given.

Figure 2.18. Stimuli used in Experiment 2. Words and icons of 3% of reading distance and a 81% contrast intensity are shown

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The same laptop, electronic device, and software program (Inquisit) as in the first experiment were used. Given that in a real-life situation the signalization is not provided in a vacuum but rather in an environment full of 'visual noise', distracting and superfluous information, and that a specific informational cue must be searched for in this environment, the task in Experiment 2 was more complex. Before each attempt, participants were instructed to search for one specific icon or word (these instructions were presented in text on the screen but read aloud by the experimenter) as fast as possible. The target icon or word could be presented either on the upper, lower, left, or right part of the visual scene. The participant responded as fast as possible by pressing the corresponding button on the electronic device (up, down, left, right; see figure 2.9). When the stimulus could not be read or identified, the participant pressed the central button, which meant 'I do not know'. Unlike in Experiment 1, they only had to give their difficulty score after they pressed the button. Whether a response (one of the four buttons) was correct or not in a given trial was electronically registered.

The experiment started with a block of 10 practice trials, that could be repeated if the participant was not yet at ease with the procedure after one practice block. Then two blocks of thirty trials were presented in random order, with the limitation that in these blocks only words and icons of sizes 1, 3, and 5% of reading distance, with the five contrast intensities, were presented. In a second block 40 trials were presented with icons of 3 and 5% size, but the participant approached the screen up to 1.5 m, so that the visual size of the words and icons was 7 an 9%. These two sizes, and the five contrast intensities, were randomized over trials. A between-blocks rest period of 5 minutes was provided.

4.2. Dependent variables and statistical analysis

Data were collected in an Excel sheet to which the verbal responses were added after the experiment. The following dependent variables were then retained for further analysis:

a) Number of correct/wrong/I don't know answers per size-contrast combination (in %),

b) Response time, defined as the time between presentation of a stimulus and the participant pressing the button, expressed in milliseconds.

These variables were then submitted to a 5 (stimulus size: 1, 3, 5, 7, or 9% of reading distance) x 5 (contrast intensities) Repeated Measures Analysis of Variance (ANOVA) with Green-Geisser correction in case of violation of the sphericity principle. For post-hoc analysis, LSD procedure was used. Eta squared was used to evaluate the effect size.

This analysis allowed to investigate how the identification of a given stimulus is affected by size and contrast in the general low vision population, without differentiation based upon the exact nature of the low vision condition. In a second analysis, the patient group was divided into two groups, one with mainly a visual acuity loss without (or very limited) loss of visual field (Limited Visual Acuity (LVA) ; n = 29), and a group with an additional significant restriction in visual field (Limited Visual Field (LVF; n = 10). As in Experiment 1, data of the control subjects served as a reference value and were not submitted to statistical analysis.

4.3. Results Experiment 2

4.3.1. Reference values (control subjects)

4.3.1.1. Response accuracy

As in the first experiment, response accuracy of the control subjects was perfect (100% correct) in all trials, irrespective of the size and the contrast of the stimuli presented.

4.3.1.2. Response time

In subjects with normal vision, response time was affected by the size of the symbols. Participants tended to respond slower (3102 msec on average) when the smallest symbols had to be found in the complex environment, with a gradual decrease in response time with increasing stimulus size (see Figure 2.19). With respect to contrast of the stimuli, no clear effect was observed. From Figure 2.19 it is clear that the main decrease in response time occurs between the 1% and the 2% reading distance condition.

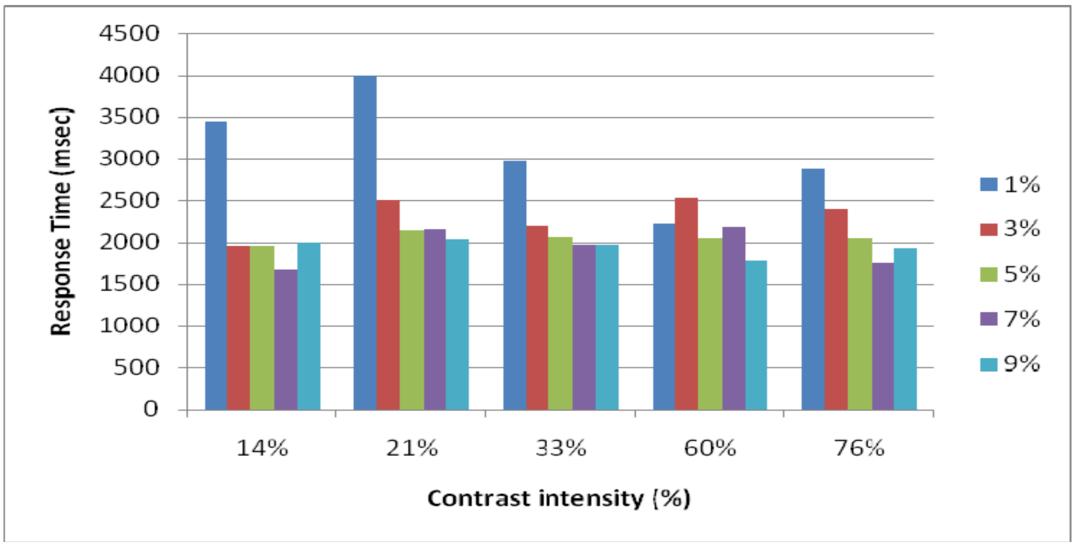

Figure 2.19. Response times of the control participants in Experiment 2. Symbol size (in % reading distance) is indicated in the legend on the right axis.

4.3.2. **Overal low vision group**

4.3.2.1. Response accuracy

Increasing stimulus size resulted in better response accuracy ($F_{4,152}$ = 216,870, $p < .001$, $\eta^2 = .85$), with significantly better accuracy with each increase in stimulus size, except for the accuracy in the 5% reading distance that was not significantly slower compared to the 7% and 9% conditions. In spite of this lack of significance, absolute scores were still somewhat higher in the 7% and 9% conditions (Figure 2.20). In the 1% condition, participants localized the stimulus in 21.0% of the trials, a number that rapidly increased to 86.4% in the 3% condition, while performance was close to maximum in the three remaining conditions.

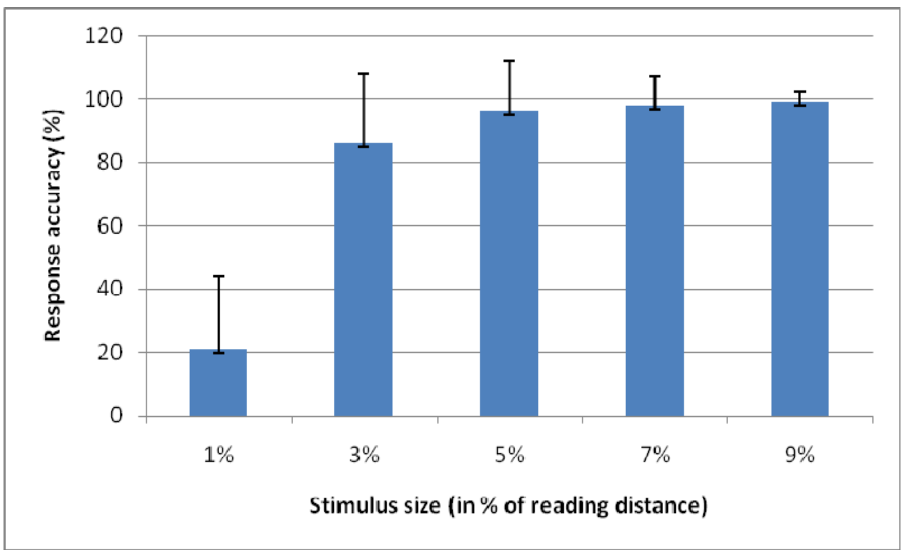

Figure 2.20. Effect of stimulus size (in % of reading distance) on the response accuracy (Exp 2) in low vision patients. Means and SDs are presented.

Increasing the contrast intensity also enhanced the accuracy in localizing the specific stimulus ($F_{4, 152}$ = 19.891, $p < .001$, $\eta^2 = .34$). Accuracy increased from the 14% condition (74.7%) to the 33% condition, in which an average score of 82.4% was attained, a figure that did not further increase in the conditions with better contrast anymore. Performance was no longer significantly different between the latter three conditions (Figure 2.21).

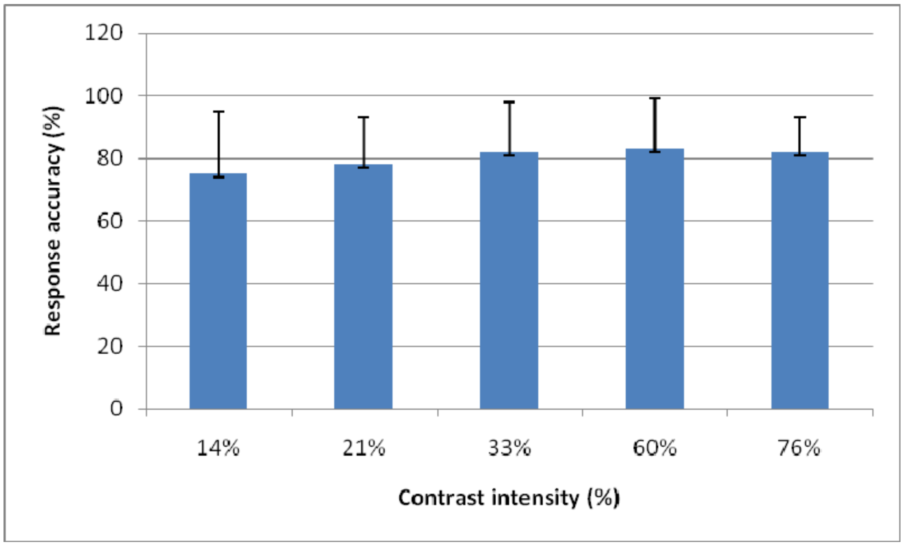

Figure 2.21. Effect of stimulus contrast on the response accuracy (Exp 2) in low vision patients. Means and SDs are presented.

A significant size by contrast interaction was observed ($F_{16,608} = 4.153$, $p < .001$, $\eta^2 = .10$), indicating that increasing the contrast intensity of the stimulus is of much importance as long as the stimulus size is below the 5% reading distance threshold. In the 1% condition, response accuracy was significantly lower in the lowest two contrast conditions as compared to the three conditions with the highest contrast ($F_{4,152} = 8.291$, $p < .001$, $\eta^2 = .18$). In the 3% condition, response accuracy was significantly lower in the 14% contrast condition as compared to the 21% condition, which was in turn lower than in the three conditions with the highest contrast ($F_{4,152} = 8.164$, $p < .001$, $\eta^2 = .18$). Above the 5% value, no differences in response accuracy were observed between the different contrast levels (all F-values for contrast were <1.0 (ns) in the 5%, 7%, and 9% conditions. The interaction is presented in Figure 2.22.

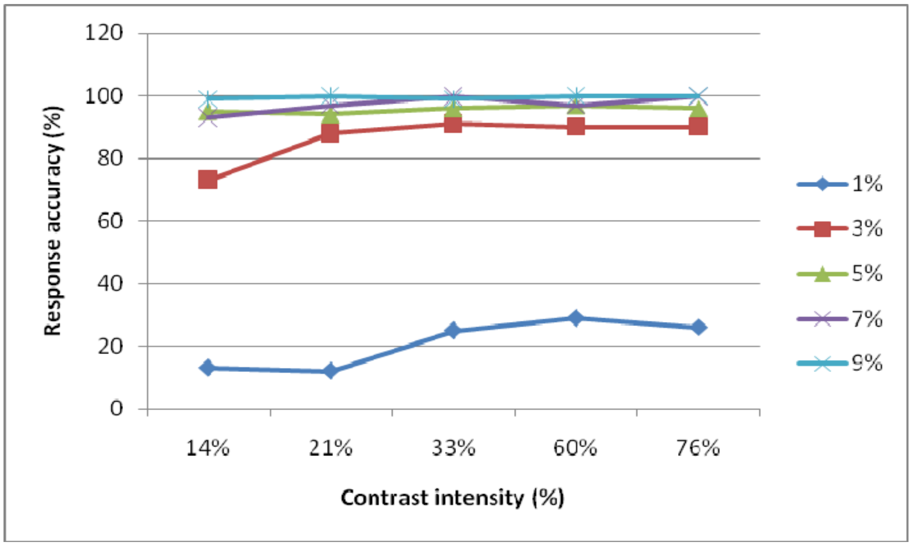

Figure 2.22. Size by contrast interaction on response accuracy in low vision patients

4.3.2.2. Response time

Increasing the stimulus size led to a significant decrease in response time from 7868 msec in the condition with the smallest stimuli to less than half of this time in the 9% condition ($F_{4,140}$ = 15.448, $p < .001$, $\eta^2 = .31$; Figure 2.23). All conditions were significantly different from each other, except for the comparison between the 5% and 7% reading distance condition.

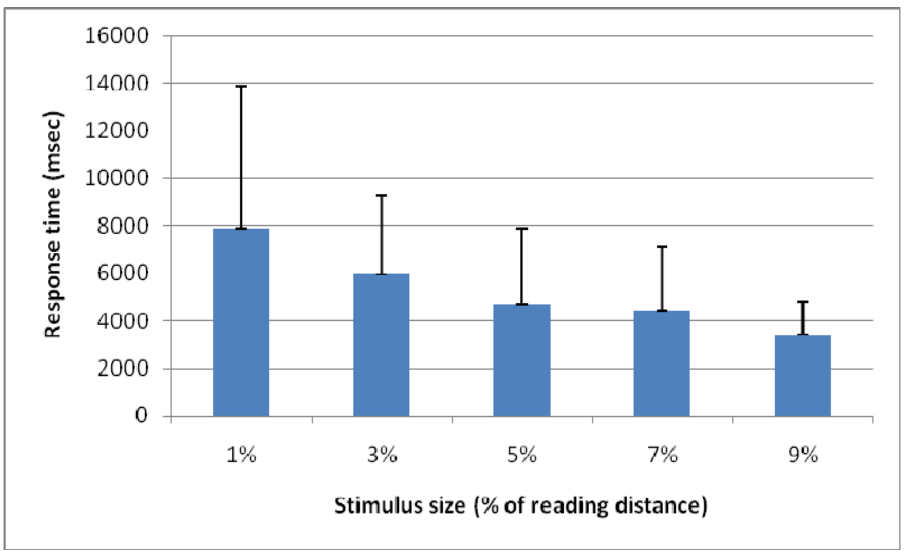

Figure 2.23. Effect of stimulus size on response time in low vision patients (Exp 2). Means and SDs are presented.

Increasing contrast intensity was accompanied by a decrease in response time ($F_{4,140} = 15.103$, $p < .001$, $\eta^2 = .30$; Figure 2.23), with a decrease from 6250 msec to 4759 msec in the conditions with the highest contrast. Post hoc analyses revealed that response time in the 33% condition was not significantly different from conditions 21% and 60%, and that the two highest contrast conditions did not differ from each other either (Figure 2.24).

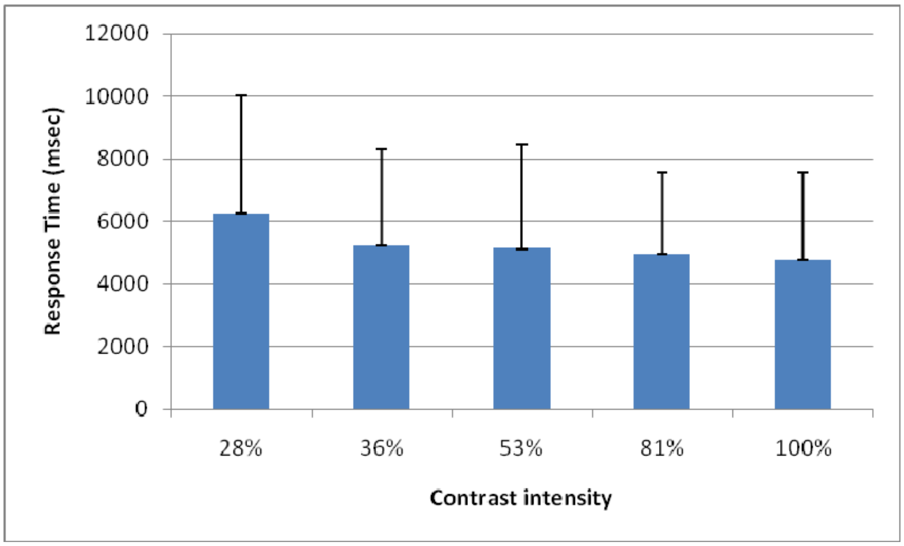

Figure 2.24. Effect of contrast on response time in low vision patients (Exp 2).

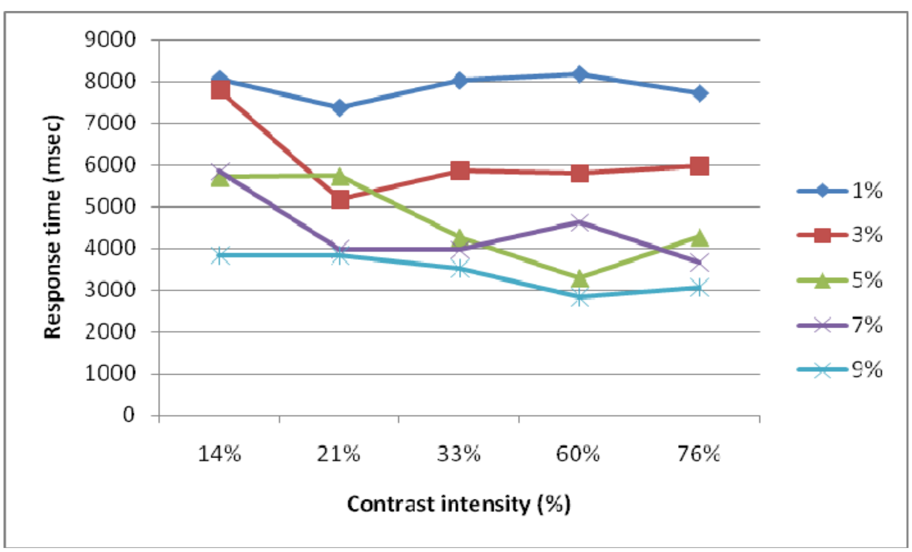

Figure 2.25. Size by contrast interaction on response time in low vision patients (Exp 2). Symbol size (in % reading distance) is indicated in the legend on the right axis.

The stimulus size by contrast interaction was also signficant ($F_{16,560} = 6.323$, $p < .001$, $\eta^2 = .15$), indicating that the effect of contrast was mainly present in the middle three stimulus size conditions. In conditions 3%, 5%, and 7% increasing contrast led to shorter response times, while this effect was much less pronounced in the 1% and 9% conditions (Figure 2.25).

4.3.3. LVA and LVF group

4.3.3.1. Response accuracy

The subgroup with the restricted visual acuity and the subgroup with a limited visual field had a similar overall response accuracy (LVA: 79.9% vs. 78.4% for the LVF group; $F_{1,34} = .011$, ns). The same main effects and interactions as in the global patient group analyses were found here. As in Experiment 1, no additional interactions with the type of low vision occurred.

4.3.3.2. Response time

When the type of low vision condition was included in the statistical analysis (LVA: Limited Visual Acuity; LVF: Limited Visual Field in addition), the main effects of stimulus size and contrast intensity as in the global group analysis remained. The LVA group tended to be faster in responding (4765 msec on average) than the LVF group (6119 msec on average; $F_{1,32} = 3.137$, $p = .08$, $\eta^2 = .09$). A border-line Size x Contrast x Type of low vision occurred ($F_{16,512} = 6.3231.663$, $p = .05$, $\eta^2 = .05$). The meaning of this-order interaction was however somewhat obscured due to the relatively low number of patients in the LVF group (n = 9 for this analysis). In Figure 2.26a it is shown that the LVA group does hardly benefit from an increase in contrast in when the smallest and largest stimuli were presented, but that their response time ameliorates in the three size conditions in between (3%, 5% , and 7% reading distance). In the LVF group (Figure 2.26b), such an effect was much less pronounced, the benefit of increasing contrast being more or less the same over the different stimulus sizes.

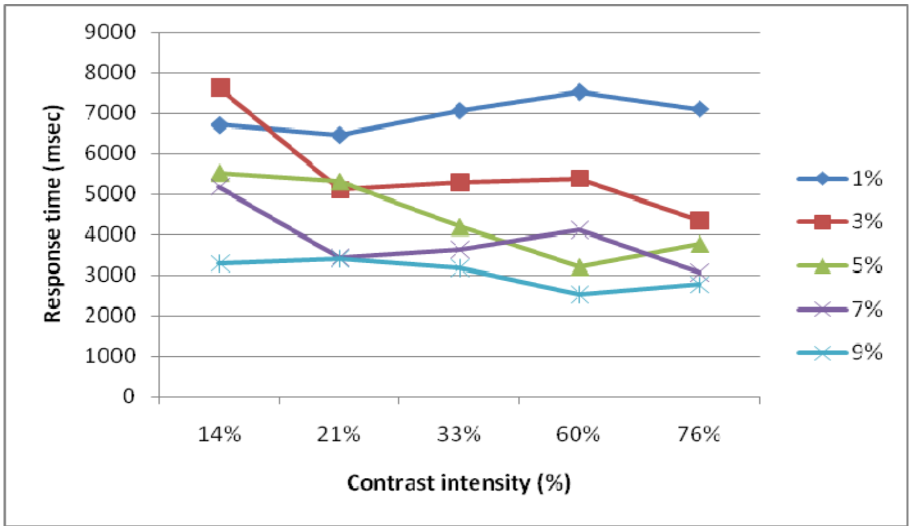

Figure 2.26a. Size x contrast x type interaction effect on response time in Experiment 2 for the LVA group. Symbol size (in % reading distance) in the legend on the right axis.

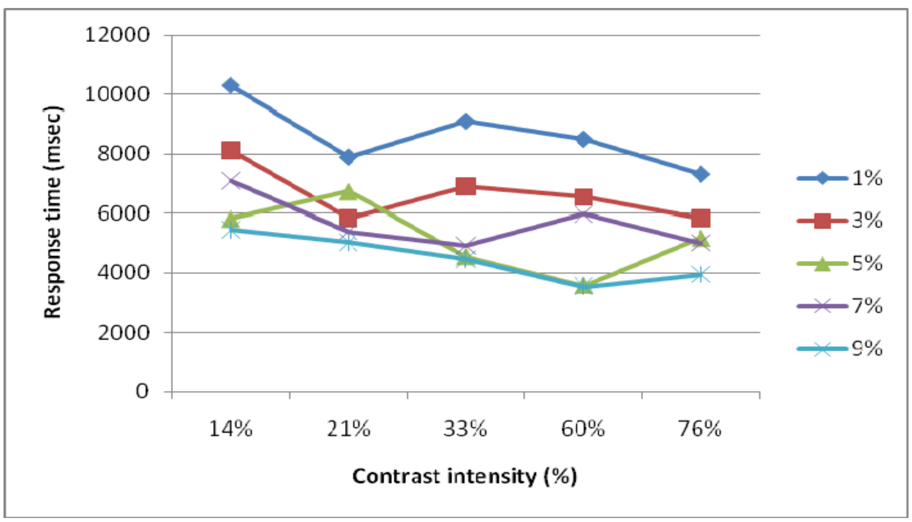

Figure 2.26b. Size x contrast x type interaction effect in Experiment 2 for the LVF group. Symbol size (in % reading distance) is indicated in the legend on the right axis.

4.4. Discussion Experiment 2

The results of the second experiment corroborate the finding of Experiment 1. As expected the time low vision patients need in order to localize and recognize a sign is about threefold compared to people with normal vision. Increasing stimulus size and contrast had the expected effects on response accuracy, although the absolute figures appear to be slightly higher. In several specific size by contrast conditions, the maximum score of 100% accuracy was obtained. It is likely that this is the result of a familiarization or learning effect. During the experiment, some of the participants were not familiar with a specific design of a sign (for example, even in 1 country several designs to indicate 'elevator' are used). After the first experiment, they had seen each sign at least four times, so that this problem did not occur in the second experiment anymore, leading to less confusion and better performance.

As in the first experiment, the effects of size and contrast were not the same for accuracy and response time. While an increase in contrast seems to be beneficial for response accuracy in the smallest signs (1% and 3%), it leads to an improvement in response speed in the 3%, 5%, and 9% conditions, while performance in the 1% and 9% are relatively unaffected. The general occurrence of the contrast only being helpful in responding faster in the 3-5-7% conditions is to be explained as follows: in the smallest stimulus conditions, participants quickly estimated that they would not be able to recognize the icon, so they immediately stopped trying, leading to short response times. In the largest stimuli condition, the stimuli were already that large that adding more contrast did not make the task easier, the patients appeared to be near their maximal response speed. However, the finding of the benefit of contrast mainly in the 3-5-7% character size range does not hold for every low vision patient. The LVF group also tended to benefit from an increase in contrast no matter what the size of the sign, while for the LVA group increasing contrast was only helpful to respond faster in the 3%, 5%, and 7% size conditions. Finally, the LVF group needs much more time to locate and identify a given sign (about 1500 msec faster, although significance was not obtained).

5. Summary and perspectives

The first aim of this study was to provide an impulse for the development for guidelines for a) the advised size of signs (words, abbreviations, and icons) in public spaces, b) the advised contrast intensity between the elements of an icon/word/abbreviation (local contrast between sign and immediate surroundings. The second aim was to study to what extent the contrast and size limitations hold in a realistic environment, in which people not only have to identify a given sign, but first have to search for it in complex visual environment.

With respect to these aims, a literature overview showed that a large amount of factors have to be reckoned with on the road to the development for such guidelines. The observation that, within the EU, a large variability in standards for visual accessibility exists underlines the need for scientific research on this issue.

Our results with respect to size of the signs show that signs should be at least 5% of the reading distance (Den Brinker et al, 2008). Optimal –but not maximal-performance was observed when contrast intensity approached a value of 75% on the white-black axis. From this study, and in particular from the interaction between size and contrast, it is clear that these two factors cannot be seen independently from each other.

During the project, several gaps and problems emerged that must be solved in the future in order to develop international guidelines for visual accessibility. First, there is a significant lack of clarity with respect to the definition and calculation of contrasts. Different authors and institutions used different methods and formulas. In addition, it is essential that clear information on this issue is available if designers and architects are supposed to use such guidelines. At the situation is now, the complexity and discrepancies in obtaining correct contrast values prevents potential users to reckon with this aspects. In contrast, evaluation of contrast should (and is) also possible without complicated or expensive apparatus. A simple quality camera can also be used for this purpose. Second, this study is limited in that a) it only took two aspects of signalization into account (size and contrast), while a lot of other factors can also affect the recognition of signs; b) contrast was limited to different degrees on the black-white axis, while we are convinced that designers and architects would prefer much more colour in constructions.

Finally, the number of questions that emerged during the study is probably greater than the number of questions answered. For example, no distinction has been made between letters and symbols used in this study, as was the case for black forms on a white background versus white forms on a black background. A further distinction between the patients in this study based upon a) the exact nature of their restriction and/or b) the trade-off between visual acuity loss and visual field loss (see Den Brinker et al, 2008) could provide further solid background for universal guidelines for visual accessibility. The latter two analysis will be performed on the dataset obtained in the near future.

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PART THREE: FINAL CONCLUSIONS AND IMPULSE TOWARDS GUIDELINES

1. Development of guidelines must be based upon an acceptable level of response correctness. In the case of visual accessibility, a correct interpretation of a sign in at least 90% of the situations seems a reasonable cut-off. This would still mean that in 1 situation out of 10, a low vision person would not be able to find his/her way independently and should rely on the help of others. We will adhere to this 90% criterion in this last part of the report, although it would be even better to aim at a success rate of 95%. It is clear that if policy makers would want to increase or decrease this value, the accompanying guidelines would change too.

2. Response accuracy in this experiment reaches acceptable levels when the stimulus size is close to 5% of the reading distance. By consequence, 5% of reading distance is advised as the absolute minimum size for the presentation of icons and words. However, it has to be noted that the results of the response time analysis did not parallel these findings. In a situation where static signs, on a location that is known in advance, must be recognized, response time only reaches optimal performance in low vision people when the symbol size is 7% or more of reading distance. When signs must be searched in a complex visual environment, response time continues to decrease into the condition with the largest stimuli (9%). So, although the sign recognition seems to be at an acceptable level as soon as the 5% size is obtained, the comfort for people with low vision in this recognition process still increases when the size of the symbols increases. This is particularly the case when signs have to be searched for. So the general advice with respect to the size of signs is that the 5% of reading distance is an absolute lower boundary under which people with low vision will face significant problems in wayfinding. This is in line with the criterion proposed by Den Brinker et al (2008) and in the UK Sign Design Guide, but is larger than the average guideline in countries of the EU (as far as the information that obtained was complete in this study). However,

3. With respect to figure-background contrast of the icons presented, the overall maximal response accuracy that was reached did hardly exceed 80%. Increasing the contrast did led to a better response accuracy, but only to a limited extent over the contrast range studied here (from +/- 70% to +/- 80% response accuracy). So in general, the size of the sign seems to be more important than the contrast intensity. The 80% response accuracy level is reached when the contrast is equal or larger than 60%, but we suggest that this is also related to the familiarity with the signs presented. A response accuracy of more than 95% is only reached when the 60% contrast is obtained in combination with a sign size of more than 5% of the reading distance. The interaction effect is found in this study is indeed more specific with respect to the formulation of guidelines. It shows that
    a. a stimulus size of about 1% reading distance is absolutely insufficient, even though an optimal contrast can significantly improve performance. Even when an optimal contrast response accuracy barely exceeds 35%. The same holds for stimulus sizes of 3% reading distance, equivalent to a maximal response accuracy of about 75%.
    b. From the moment the stimulus size reaches or exceeds the 5% reading distance threshold, the effect of contrast on recognition success diminishes, but it still helps in the speed of recognition. In the 5% condition, the effect of contrast still accounts for 7% correct responses.

The tables below provide an overview of the relation between sign size and contrast, and can be used as a rule of thumb in dealing with the trade-off between size and contrast. Success rates of 95% and more in a particular condition are indicated in green, accuracy between 90-95% in blue, and insufficient response level in red. A visualization is presented in Figures 3.1 and 3.2.

Table 3.1.

Success rates for different size/contrast combinations in a recognition task (Red = insufficient combination; Blue = borderline; Green = sufficient). Contrast is expressed according to the Weber formula, size is in % of reading distance.

Contrast **Size**	**14%**	**21%**	**33%**	**60%**	**76%**
1%	**12**	**15**	**19**	**33**	**35**
3%	**60**	**76**	**79**	**77**	**77**
5%	**91**	**91**	**93**	**94**	**97**
7%	**94**	**95**	**95**	**96**	**98**
9%	**97**	**94**	**97**	**99**	**97**

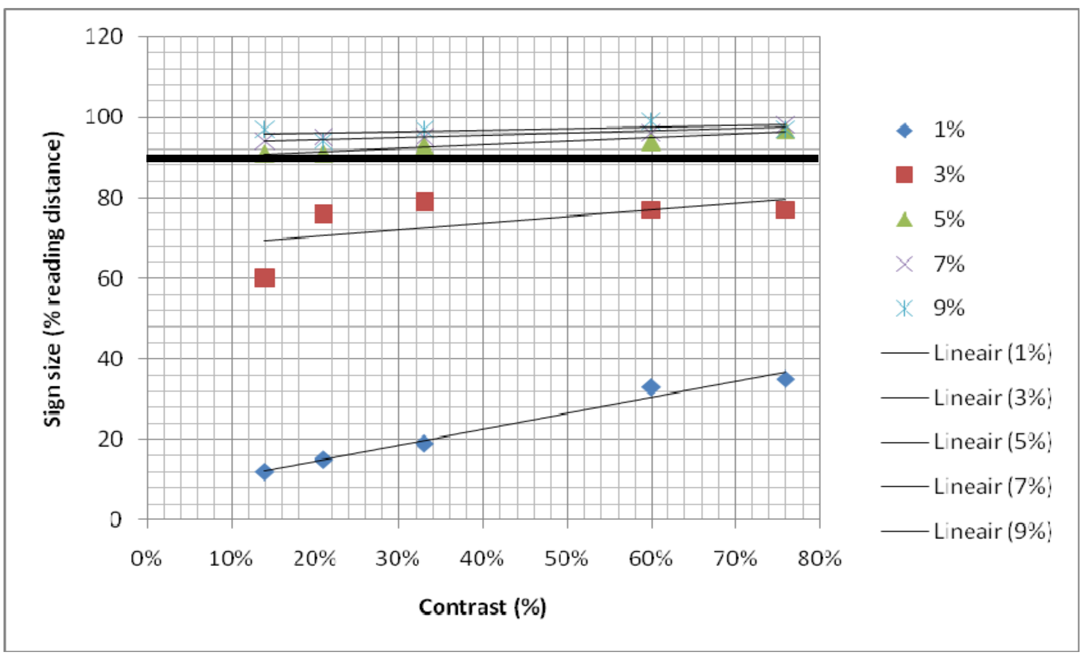


Figure 3.1. Size/contrast combinations with respect to a 90% accuracy boundary. All combinations below the black 90% are insufficient for people with low vision.

Table 3.2.

Succes rates for different size/contrast combinations in a localizations/recognition task (Red = insufficient combination; Blue = borderline; Green = sufficient). Contrast is expressed according to the Weber formula, size is in % of reading distance.

Contrast **Size**	**14%**	**21%**	**33%**	**60%**	**76%**
1%	13	12	25	29	26
3%	73	88	91	90	90
5%	95	94	96	97	96
7%	93	97	100	97	100
9%	99	100	99	100	100

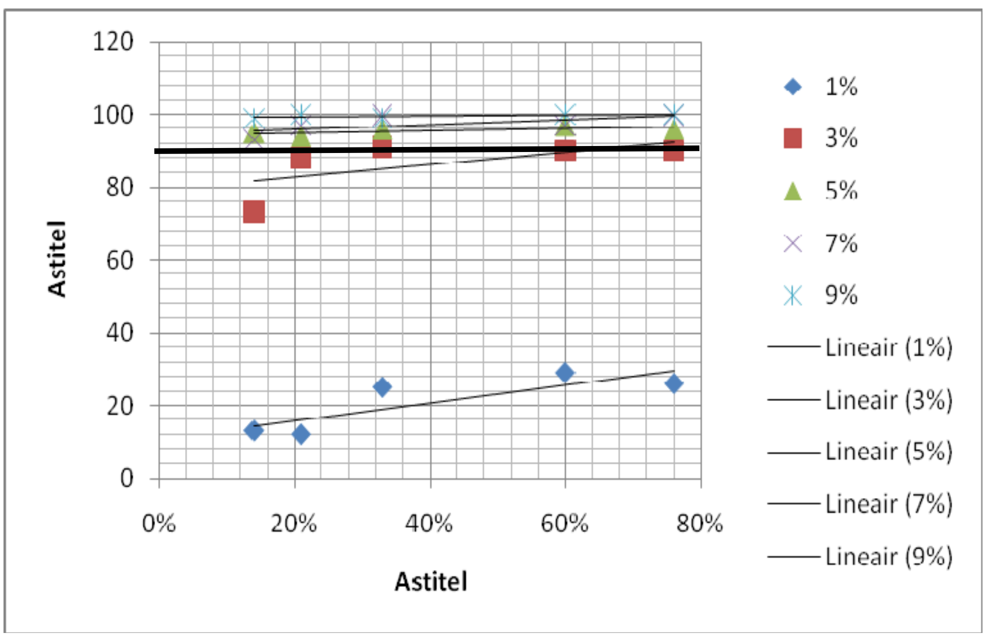


Figure 3.2. Size/contrast combinations with respect to a 90% accuracy boundary. All combinations below the black line are insufficient for low vision patients.

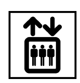
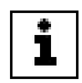
4. From the observation that sign recognition in the second experiment was slightly better compared to experiment 1 (the 90% criterion was already reached in some of the 3% size conditions, and the maximal score was

obtained in 6 out of the 25 experimental conditions), it is clear that performance improves as familiarity with the signs is better. In the first experiment, some subjects spontaneously mentioned that they recognized a specific form, but could not name it because they were not familiar with a specific icon. From this, the need for uniform design for signs in all countries of the EU is obvious.

5. These guidelines hold for the general low vision group, but within this group some patients will need much more time to recognize an icon or word than others. Patients with a more or less intact visual field show a linear decrease in response time with increasing size, while patients who have a limited visual field in addition to visual acuity problems do not seem to benefit from an increasing stimulus size with respect to the response speed. In the latter case, the stimulus size exceeds their static visual field so that they have to change their line of sight be eye or head movements, which leads to longer response times. As already stated, this is more a matter of comfort than of necessity. Both groups finally succeed in recognizing the same sign, but the group with a restricted visual field as well as a restricted visual acuity need more time. Related to this issue, further analyses of the dataset obtained in this project will allow to calculate a correction formula to compensate for a lower figure/background. For example, when a contrast of only 30 can be obtained in a given situation, the character size must be increased in order to obtain an acceptable result in recognizing and understanding a sign. This compensation formula will of course have its limitations because character size cannot be increased infinitely without bringing people with visual field restrictions in difficult situations. From our data it was already apparent that people with normal vision are not hampered by an increase in character size above the 5% of critical reading distance criterion, but low vision patients with limited visual fields tend to respond slower again when the character size is 9% of critical reading distance. It has however to be noted that the group of low vision patients with visual acuity limitations largely outnumber the group with visual field problems.

6. It has to be noted that the average visual acuity of the patient group in this study was better than the 0.05 boundary in the low vision definitions. From this, it is expected that further analyses (than can also be done on this dataset) will reveal that the group with the lowest visual acuity will still benefit from a further increase in character size up to 7 or 9% of the critical reading distance.

7. Although not the aim of this project, during the experiments it became clear that a lot of commonly used symbols are composed of too many small details, which are very hard to identify by people with low vision. This occurred even though we eliminated very detailed symbols before the experiment. Even if the sign size is increased well above the 5% threshold, this remains a problem that prevents them from fully understanding the sign. The sign for ‘information point’ is an example of good practice here, while the sign for ‘elevator’ is not in this respect.

   So it would be advisable to compose the signs with elements with dimensions that are comparable to the dimensions of letters in words. From this point of view, the same guidelines with respect to the size of signs and words could be used if a international standardization would be considered.

8. This project was limited to the investigation of the effect of contrast on a black/white axis, and the size of the signs. On the one hand, contrast is a very complex item on which much inclarities in the literature emerge. In the future a distinction between colour contrast and luminance contrast is imperative, so that future guidelines could also reckon with the demands and wishes of designers and architects. From the literature is is clear that different definitions and formulas to obtain contrast are not very constructive towards global guidelines that are easy to understand and to use for all parties involved in the design and construction of buildings an public places. On the other hand, contrast and size are only two of the factors that might affect the visual

accessibility (see literature). Factors such as lighting, positioning, design of the signs, etc.. and the interactions between each other must certainly be studied before it will be possible to formulate international guidelines.

9. Although this study focused on people with low vision, visual accessibility should be an issue from the very first stages in designing and construction buildings. It should be part of a general design for all package.

10. Finally, the limitations of a laboratory based study must also be acknowledged. It would be applauded to plan a follow-up study to evaluate the conclusions found in these experiments in a real-life situation, with normal illumination, in the presence of other users of facilities.

In summary, the guideline proposed by Den Brinker et al (2008) is generally confirmed in this project, but this cannot be seen as a golden rule for every person of the low vision population. Further analyses on the obtained dataset must reveal to what extent this guideline holds for people with a very low visual acuity (not that the average acuity in this group was above 0.05) and control subjects with normal vision. The correction formula for contrast when a given character size cannot be obtained or must be read by low vision patients with a particular acuity and/visual field, must be calculated from this dataset. Such analyses were however beyond the aims and time constraints of the project reported here. Additional time and financial support is desirable to fully unravel these issues.