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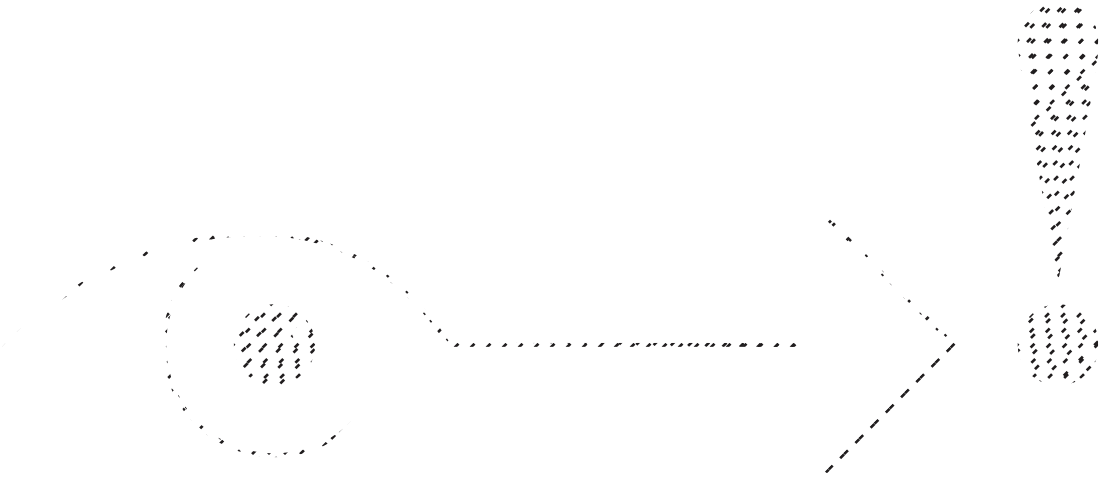

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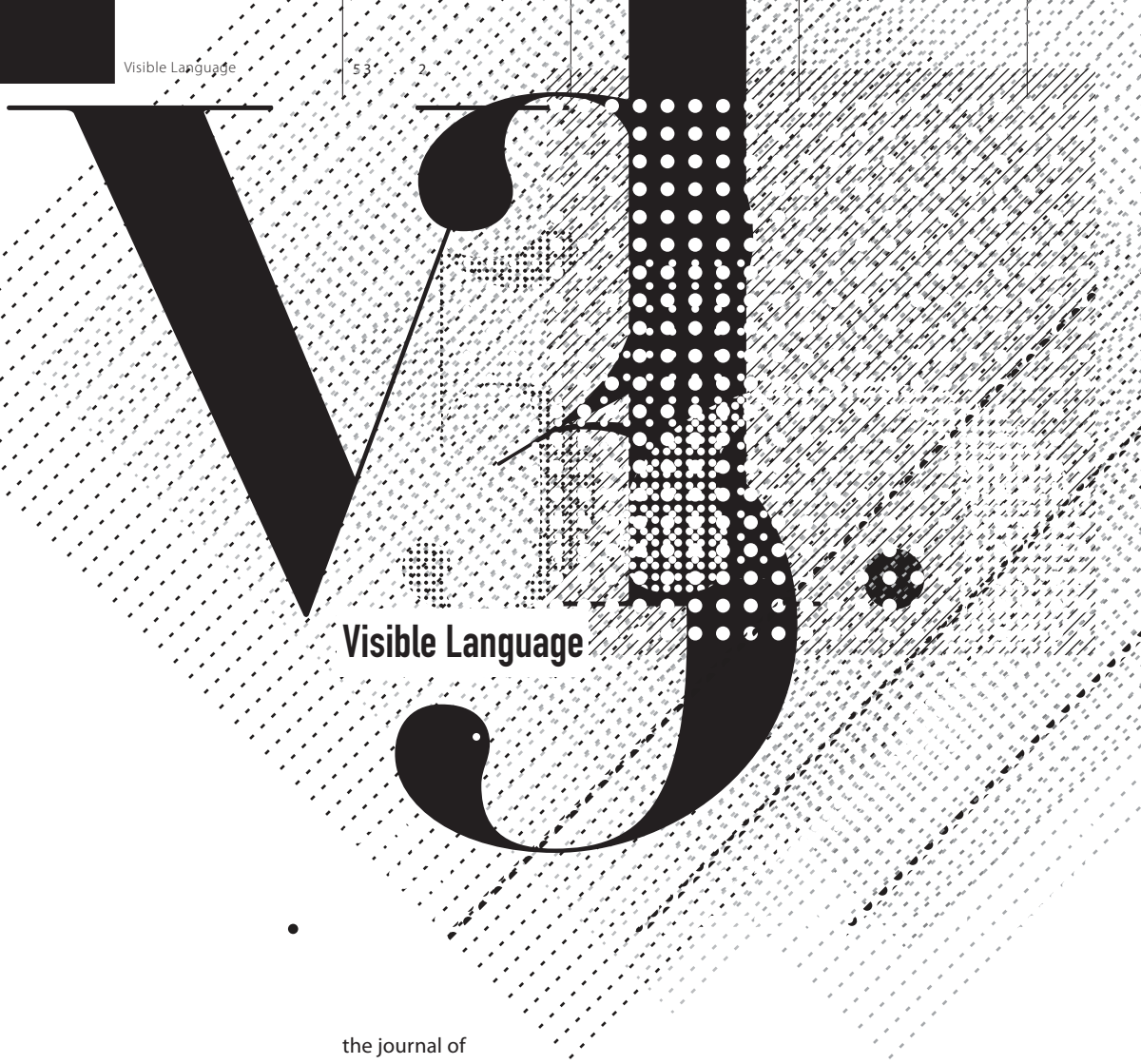

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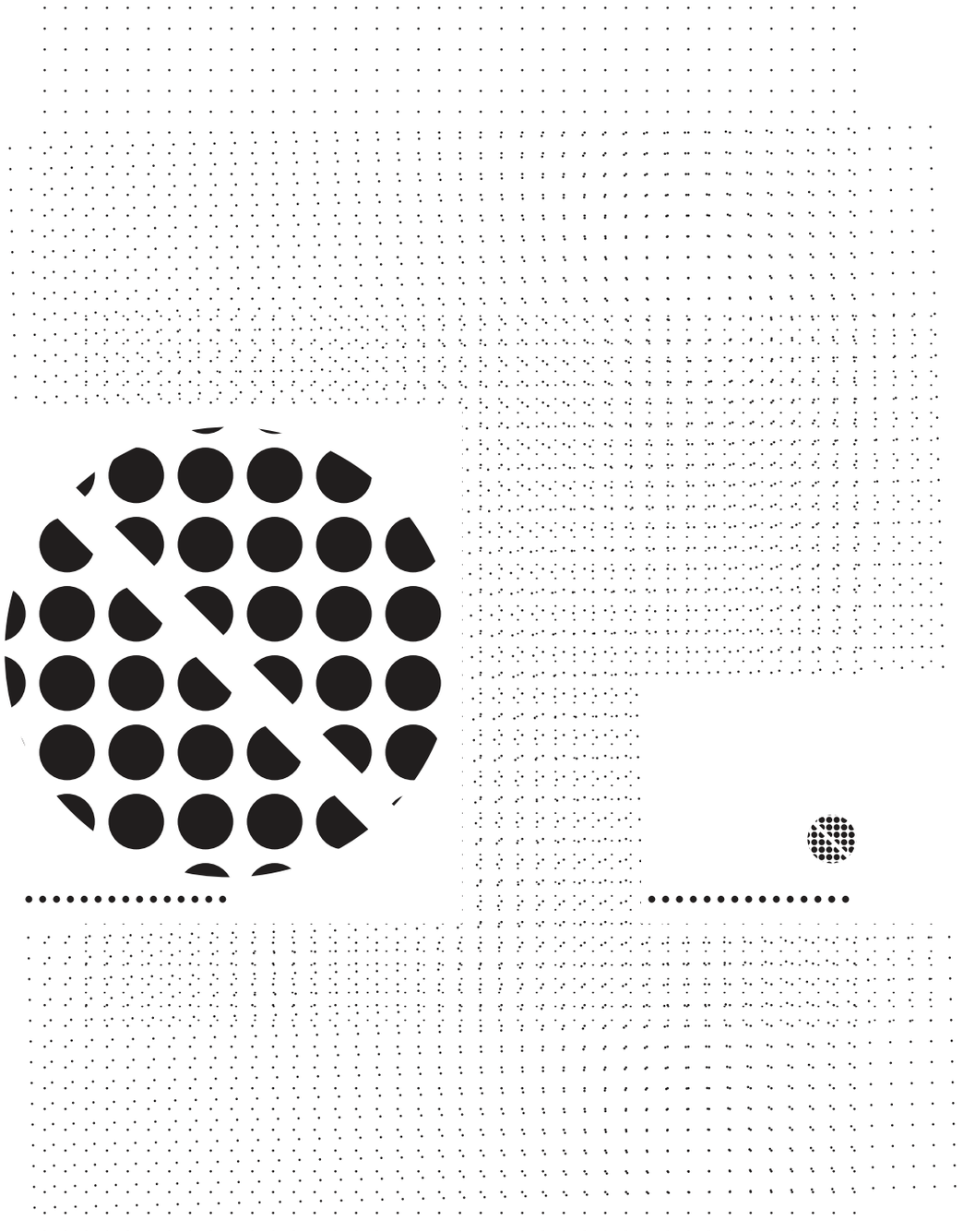


Legibility of Pharmaceutical Pictograms: Towards defining a paradigm

Pia Pedersen

The design of medicinal information in leaflets and labels is often criticized for not meeting patients' needs. For that reason, there is an increasing focus on how the use of pictures, such as pictograms, may benefit patients on their medical journey. However, before a pictogram can be comprehended it must be legible, which may be a challenge when pharmaceutical information has to be conveyed. Within a limited space many visual details need to be included in order to clarify the intended meaning.

While we have abundant information about the comprehension of pictograms, we know very little about the legibility – the ability to visually identify objects – of pictograms. By looking at legibility research into pharmaceutical pictograms from a design perspective, this paper demonstrates that legibility is not prioritized either in theory or in practice. In order to proceed with the use and implementation of pictograms in, for example, patient information leaflets and labels, we need to know more about the features that constitute legibility. To create a research foundation, this paper draws on knowledge of visibility and legibility from related domains. This forms the basis of a discussion of the need for future research to focus on legibility issues, amongst others by incorporating design knowledge into experiments.

Introduction

Medicines, as well as regulations regarding ways to inform and educate patients about medicines, have increasingly become mass-produced. For instance since 1992, the EU has required that printed drug information in the form of leaflets be enclosed with all dispensed medicines (see Waarde 2017). These leaflets and the pharmaceutical packaging are subject to legislation and guidelines within the EU as well as nationally. Research into pharmaceutical information embraces several disciplines, including pharmacology, business communication, language science, graphic design and information design. Across these disciplines the research findings indicate that the EU rules – despite good intentions – prevent the design and development of information that fits users' needs (Waarde 2017, 2008b, 2010, 2008a, Maat and Lentz 2010, Askehave and Zethsen 2014, Waarde and Spinillo 2015, Dickinson and Gallina 2017).

Meanwhile, an increasing number of people are taking medicines, and we are given more responsibility for our use of medicines. Still people die because of medication errors (WHO 2017). Many patients find it difficult to absorb medical information because of their mental state and the technical terminology (Houts et al. 2006, 174). These problems are exacerbated in some groups, like the older population, which is growing worldwide (UN 2017).

One way of improving the efficacy and clarity of medical information could be through graphic symbols such as pictograms. The current use of the term pictogram often refers to a simple and stylized drawing that resembles the idea or concept it is meant to convey (see Tijus et al. 2007). Pictograms are used in many different contexts, such as wayfinding, traffic information and product instructions. When they are employed to help patients understand their medicine treatment, they are usually called *pharmaceutical pictograms*. Their purpose is to help people see, understand, recall and adhere to information about medicines such as instructions, symptoms, precautions, warnings and side effects. A well-researched library of pharmaceutical pictograms is the so-called *USP (The United States Pharmacopeia)*, which was initiated by The United States Pharmacopeia Dispensing Information (USP-DI) over 30 years ago.

According to the European Commission's guidelines symbols and pictograms in leaflets are allowed as long as they are easy to understand and not of an advertising nature and do not in any way replace the text (EC 2009, see Annex 1, Point 8). However, there are no visual guidelines or exemplifications on how to design or implement pictograms. The implementation of pictograms on labels and leaflets has been tested for patient preference, comprehension and adherence (e.g. Chan and Hassali 2014, Dowse and Ehlers 2005, Mansoor and Dowse 2003, Ng, Chan, and Ho 2017, Shiyanbola et al. 2016), however to a lesser degree than stand-alone pictograms. Moreover, in spite of their potential to help people understand their treatment, the use of pharmaceutical pictograms is still limited (Kanji, Xu, and Cavaco 2018, 1) but should be considered seriously (Mansoor and Dowse 2003, 1008).

While some research fails to confirm the benefits of adding pharmaceutical pictograms to labels and PILs (Hwang, Tram, and Knarr 2005, Wolf et al. 2010, Morrell, Park, and Poon 1990, Chan and Hassali 2014, Hämeen-Anttila et al. 2004); it is generally agreed that they can improve patients' ability to notice, understand, recall and adhere to information about their medication (see reviews by Del Re et al. 2016, Barros, Alcântara, Mesquita, Santos, et al. 2014, Houts et al. 2006, Katz, Kripalani, and Weiss 2006, Choi 2011, Dowse and Ehlers 1998). Pharmaceutical pictograms could thus be a valuable tool for patients and for pharmacists and other healthcare professionals who have a responsibility for helping patients to take their medicine correctly (Kanji, Xu, and Cavaco 2018).

Ideally, an effective pictogram should clearly convey its intended meaning to all groups of patients across age, literacy, language and culture (Dowse and Ehlers 1998, 109). While this is difficult to achieve, and although it is recommended that pharmaceutical pictograms not be used without some written or verbal explanation (Houts et al. 2006, Katz, Kripalani, and Weiss 2006, Barros, Alcântara, Mesquita, Santos, et al. 2014), it is crucial that they are as unambiguous as possible in order to avoid misunderstandings that could lead to serious medication errors. In addition, before a pictogram can be understood it must be legible (Boersema and Adams 2017, 306, Wogalter, Conzola, and Smith-Jackson 2002), which, from a visual perception perspective, may be challenging for two reasons. First, pharmaceutical pictograms are often complex, because they represent objects or concepts that are complicated or closely related; thus, details need to be added to make the different pictograms comprehensible and distinguishable. To show a breastfeeding woman, for instance, the baby and the breast must be displayed. When showing side effects such as headache and dizziness, a face, and some detailed variations in the form of *contextual clues* must be shown to further understand and differentiate their meanings (see Zender and Mejía 2013, Lesch et al. 2013). It is not enough to show a simple filled icon of a woman like we see in the toilet pictogram (*see Figure 1*). Second, space is an important aspect of the implementation of pharmaceutical pictograms on e.g. patient information leaflets and labels (Dowse and Ehlers 1998, 114). However, if reduced in size as in Figure 2, visual details may blend together and reduce legibility. Considering the growing older population, who often suffers from impaired vision, it becomes clear that solving legibility issues in pharmaceutical pictograms is important.

female toilet

are you breastfeeding?

Figure 1

Pharmaceutical pictograms often require more contextual clues and details to convey their message. (left): Pictogram for female toilet.(right): Pharmaceutical pictogram for 'are you breastfeeding?'.

Source: USPC

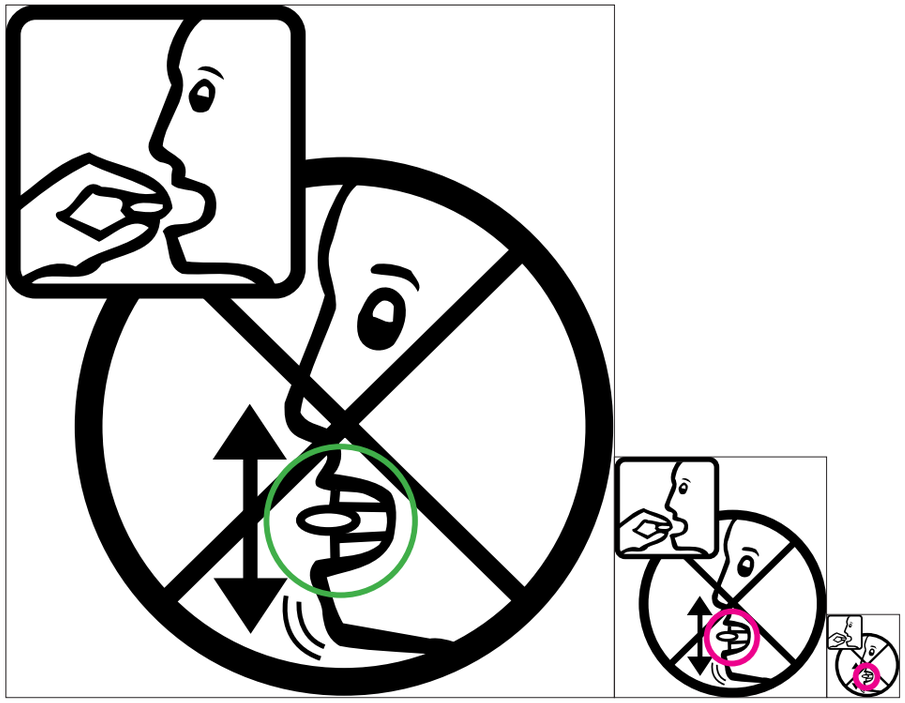


Figure 2

Essential details may be blurred when pictograms are reduced in size. In this example the pill could easily be misinterpreted as a tongue, and thus confuse the reader.

Source: USPC

comprehensibility of pharmaceutical and other health-related pictograms when it comes to selecting the right content (e.g. Korenevsky et al. 2013, Strauss and Zender 2017, Zender and Mejía 2013), cultural sensitivity (e.g. Kanji, Xu, and Cavaco 2018, Mansoor and Dowse 2004, Zender and Cassidy 2014, Kassam, Vaillancourt, and Collins 2004), health literacy (e.g. Sharif et al. 2014, Hill 2006) and age-related problems (e.g. Choi 2011, Ng, Chan, and Ho 2017, Knapp et al. 2005, Lesch et al. 2013). However, when it comes to legibility very little research exists.

Within letterform research – a field with increasing focus on legibility – legibility is understood as an isolated aspect in relation to perception and is defined as the ability to visually differentiate and identify the characters of a typeface (see Beier 2016, Beier and Larson 2010). Legibility features itemized in letterform research are for instance crowding, size, stroke thickness and contrast. Such issues are often neglected in existing research on pharmaceutical pictograms, because there is a tendency to either prioritize comprehensibility or understanding legibility as comprehensibility (e.g. Soares 2013, Kanji, Xu, and Cavaco 2018, Ringseis and Caird 1995, Pires, Vigário, and Cavaco 2016). Another tendency is to disregard design knowledge such as the ISO design guidelines, as will be exemplified with a few USP pictograms. It also appears that some studies include pictograms in labels without considering the layout (for example in Chan and Hassali 2014)

or assessing the quality of the pictograms before testing them (for example in Hwang, Tram, and Knarr 2005). Other studies ignore the design of the material (for example in Hämeen-Anttila et al. 2004) and use pictograms that are either of poor quality or do not fit the target group (for example in Hill 2006, Kripalani et al. 2007).

The consequence is that we do not know which variables affect performance. In order to start answering these questions, this paper wishes to establish legibility as an indispensable focus area within the research of pharmaceutical pictograms. First the importance of legibility is highlighted through selected examples of pharmaceutical pictograms and knowledge from typeface legibility research. Secondly a literature review demonstrates how little we know about the legibility of pharmaceutical pictograms; hence relevant knowledge from related domains is brought forward. Finally the paper discusses the need for future research to focus on these matters, proposing that a design-oriented approach could bring new knowledge to the field.

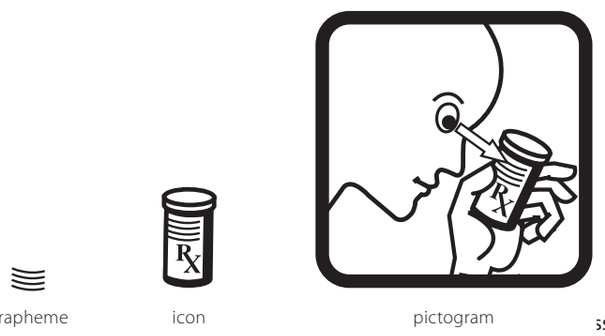
Pharmaceutical pictograms

In order to examine pharmaceutical pictograms, it is important first of all to determine what the term *pictogram* signifies. The proper use and classification of the term has been subject to much debate and confusion. Pictograms are indeed used in many different contexts and places and have been studied over a range of different disciplines, such as semiotics, graphic design and cognitive psychology. The taxonomy formulated by Strauss and Zender (2017) provides a helpful explanation, because it draws upon the different disciplines and categories. Their taxonomy differentiates between three terms: *graphemes*, *icons* and *pictograms* (*see Figure 3*). Graphemes are small, visual elements that do not necessarily have an inherent meaning. Icons are made of graphemes to represent simpler concepts or items. Pictograms, then, have the most complex character, because they consist of one or more icons to help express more complex ideas (Strauss and Zender 2017, 8). Such a distinction is useful when talking about legibility, because it forms a framework for isolating different parts of a pictogram.

Figure 3

The difference between graphemes, icons and pictograms illustrated through the USP pictogram 'Read the label'.

Source: USPC



and Zender's taxonomy to indicate a type of graphic symbol that bears a visual resemblance to the object or idea it represents. The term *graphic symbol*, then, more broadly denotes – as in the ISO guideline – a "visually perceptible figure used to transmit information independently of language" (ISO 22727:2007(E) p. V). Other terms, such as symbols, pictures or icon signs etc. are employed in accordance with their original source.

The two most comprehensive pharmaceutical pictogram families that have been tested, validated and disseminated are the United States Pharmacopeia (USP) pictograms and the pictogram software developed by the International Pharmaceutical Federation (FIP). The USP pictograms, as mentioned, have been developed under the United States Pharmacopeia Convention, a project that was initiated back in 1987 (Dowse and Ehlers 1998, 113). Their purpose is to assist in the proper use of medicines across literacy and language barriers. In total there are 81 pictograms that can be grouped into three different types: First, 'prescription instructions', second, 'purpose for use', and third, 'cautionary statements' (Whitaker 2015). The USP pictograms are free and – although designed for use in the United States – have been tested and validated for comprehension in other countries such as South Africa (Dowse and Ehlers 2004, Dowse and Ehlers 2001, Mansoor and Dowse 2004), Iran (Zargarzadeh and Ahmadi 2017), United Arab Emirates (Sharif et al. 2014), India (Bansolta 2012), Pakistan (Yasmin et al. 2014), Hong Kong (Ng, Chan, and Ho 2017), UK (Knapp et al. 2005), and Portugal (Soares 2013).

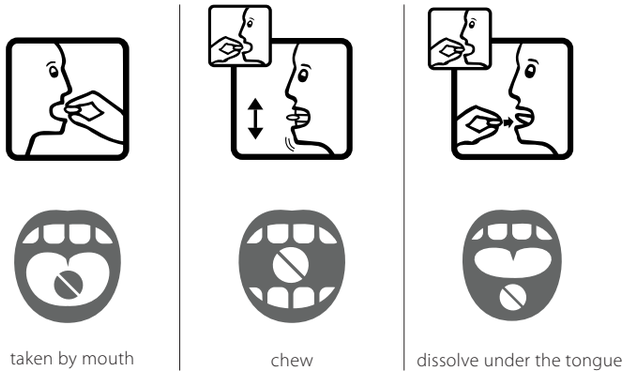
The FIP-pictogram family has been developed as a pictogram software that can be downloaded from the FIP website (last update: 7 February 2017). Their *Pictograms Project* was initiated in 2004 to support pharmacists in their daily work. Like the USP pictograms, their purpose is to create a common language between professionals (pharmacists) and patients. The approximately 100 pictograms are grouped into different purposes ('Dose and Route', 'Frequency', 'Indications', 'Precautions' and 'Side Effects'); additional pictograms have been designed to account for cultural differences in e.g. Gabon or countries in East Asia. According to the FIP website, all pictograms have been designed in a consistent style to avoid any confusions (FIP). Furthermore, they have been tested and validated on different cultures, ages and levels of education (Sorfleet et al. 2009, Grenier et al. 2011, Berthenet, Vaillancourt, and Pouliot 2016) and even apply to the visually impaired (FIP).

Apart from the FIP and USP, there are also smaller local pictograms, such as the Japanese pictograms developed by The Risk/Benefit Assessment of Drugs Analysis and Response (RAD-AR) Council of Japan, the Polish Patent Office (see Merks et al. 2018), the Dutch Pharmaceutical Society (Waarde 2015) or the Danish medicine icons developed by Dansk Lægemiddel Information A/S (DLI A/S).

Figure 4 illustrates how the same instructions are visualized in different ways. Even though the USP pictograms and the Danish DLI icons are meant for two different media, their differences in shape, style, contrast etc. indicate that there is no standard in designing pharmaceutical pictograms.

(above) The USP pictograms designed primarily for health care professionals to give medical instructions. (below) Danish icons designed for web use.

Source: DLI and USPC



Standards

Today, there are several international as well as national standards for designing and testing graphic symbols, also when it comes to perceptual quality. The most important international standards are probably the ones developed by the already mentioned ISO (International Organization for Standardization), and, from a national perspective, the ones developed by ANSI (American National Standard Criteria for Safety Symbols). As stated by Boersema and Adams (2017, 304) the ANSI standards cover many of the same areas as ISO, and both standards are frequently employed to test pharmaceutical pictograms. The majority of comprehension studies base their evaluation on either the ISO or the ANSI criterion or both, hence safety symbols must reach a minimum comprehension level of 67% (ISO) and 85% (ANSI). To date, there are still many pharmaceutical pictograms that fail to meet the ISO or ANSI comprehension criteria (see Kanji, Xu, and Cavaco 2018, Barros, Alcântara, Mesquita, Bispo, et al. 2014, Waarde 2015, Merks et al. 2018, Montagne 2013).

ISO provides an Online Browsing Platform (OBP) with graphical symbols, testing methods and design guidelines[1]. In the OBP there are over 4000 graphical symbols dispersed in 'Public Information Symbols', 'Safety Signs', 'Water Safety Signs', 'For Use on Equipment' and 'Symbols for Diagrams'. One should notice, however, that not all graphic symbols in the database have been tested for comprehension and should therefore be used with caution (Boersema and Adams 2017, 308). Boersema and Adams also argue that before designing a new symbol or pictogram one should look for a standardized version in the platform (ibid.). A quick search on 'medical', 'medicine' and 'pharmaceutical', however, reveals that apart from an ambulance there are no pharmaceutical pictograms in the standard.

The ISO design guidelines are different whether they are for public information symbols (ISO 22727:2007) or safety symbols (three parts of ISO 3864) for which different rules apply. ISO 22727:2007, for instance, provides rules for visual features such as line widths, minimal size of details and rules for illustrating water and human figures. The guideline also encompasses a template for designing symbols within which one can account

1 For an overview of the ISO standards for graphic symbols, see Boersema and Adams (2017).

for specific line thicknesses. Hence, lines should be at least 2 mm thick (in some special circumstances they can go down to 0.5 mm) and spacing between lines should be minimum 1 mm. Then again, the ISO standard recommends filled areas because they improve legibility compared to outlines (ISO 22727:2007, p. 13). The majority of the USP and FIP pictograms, however, are drawn in outline and do not follow the visual recommendations of the guidelines (e.g. line width, negation mark etc.). Figure 5 illustrates how two USP pictograms are drawn with lines the majority of which are below the recommended 2 mm. This issue is evident in some of the FIP pictograms, too, (not displayed here) that also make use of thin strokes.

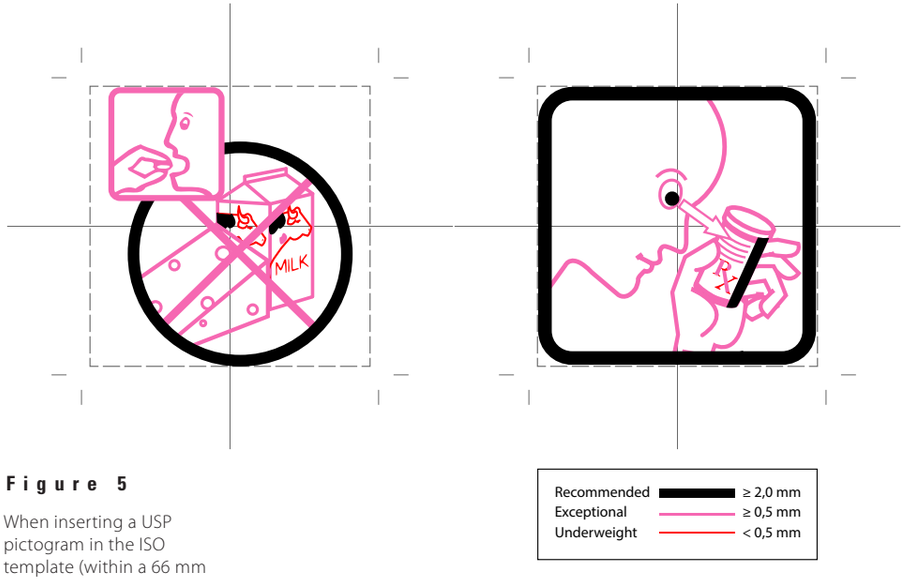


Figure 5

When inserting a USP pictogram in the ISO template (within a 66 mm broad margin), it becomes clear that the standards are not followed. The black areas are those that fit the standard recommendation for line width. The pink lines represent parts that are below between 0.5 and 2 mm, the red for lines below 0.5 mm. When the pictograms are scaled so that the frame extends the margin, the thinnest lines in red widen to ca. 0.5 mm, which according to the ISO recommendation should only be used exceptionally.

Source: USPC and Author

Three different test methods have been developed by ISO for graphical symbols: first, a method for testing comprehensibility (ISO 9186-1:2014); second, a method for testing perceptual quality (ISO 9186-2:2008) and third, a method for testing symbol referent association (ISO 9186-3:2014). The second, ISO 9186 -2:2008, mentioned earlier in this article, is relevant in this context, as it helps to identify problematic elements in a pictogram from a visual perspective. This standard includes guidelines for apparatus and test material, i.e. print quality, viewing distance, lighting level in test room, symbol size and color. Symbols should be tested in at least two sizes, where the large one – 8x8 cm at 2 m viewing distance – helps decide whether depicted elements are named as intended, and the small size determines whether elements are recognizable in a normal setting of viewing conditions. In the method, respondents are asked to identify and describe the different elements of a symbol. Respondents may use all the time they need to see and describe the symbol. A correct answer can either be an accurate description of the shape, or the actual name of the object depicted. The test method also accounts for symbols that must function in small sizes (Boersema and Adams 2017, 311).

Legibility

Within letterform research there is a growing body of knowledge on typeface legibility (for example Chung, Mansfield and Legge 1998, Sawyer et al. 2017, Beier, Bernard and Castet 2018, Thiessen et al. 2015) that could form the basis of determining what constitutes pictogram legibility. Hence, from some visual aspects, pictograms and letters can be compared, because both consist of black and white shapes, counters and strokes. While this assumption requires a more comprehensive discussion, for the present purpose, I will borrow some definitions to help determine *visibility* and *legibility*.

Whilst looking into the impact of familiarity on reading, Beier (2009) argued that visibility and familiarity can be isolated from each other. According to Beier, *visibility* is the "clarity of letters isolated from the influence of typeface familiarity," whereas *familiarity* is a matter of how often we have been exposed to a typeface and how similar the features between letterforms are (Beier 2009, 23). *Legibility*, then, refers to both visibility and familiarity and is about the design and differentiation of the individual characters in a typeface. This distinction is useful in the present context, as it is the first step towards understanding what specific variables improve legibility.

Typeface legibility research has its roots in both typography and psychology; however, historically there has been scant collaboration between the two fields (Dyson 2013, Beier and Dyson 2014). While there has been a tendency to simply compare the impact of different typefaces on reading, there is now a greater awareness of the importance of incorporating typographic knowledge into the test material (Beier and Dyson 2014, Beier 2016).

This form of knowledge, which is based on practical experience and also known as 'tacit knowledge' (Polanyi 2005 (1958)), can add to the creation of test material because of the designer's ability to understand form and conceive of new shapes. Hence, when simply comparing different typefaces, there are too many variances in weight, proportions, contrast and styles from one typeface to another. Instead, by knowing how to isolate one visual feature, we can easier control it and determine how this particular feature affects legibility (Beier and Dyson 2014). For instance, comparing letters with similar proportion, contrast and style, but only altering their weight provides us with evidence of how this particular variable affects legibility, see Figure 6. In the present context, this clarifies that in order to understand the principle of legibility we must first recognize the different variables that are at stake.

Figure 6

In the first example of this illustration the only parameter that varies is the stroke weight; in the second there are several parameters that vary, such as stroke weight, width, letter skeleton, contrast and proportion. The example is based on the typefaces: Left: Helvetica UltraLight, Helvetica Light and Helvetica Regular; right: Helvetica UltraLight, Bodoni 72 Book and Futura Bold.

Beier's definition of visibility resembles the International Organization for Standardization (ISO) definition for graphic symbols. ISO (9241-3, 1992) defines visibility as "the visual properties of a character or a symbol that determine the facility with which it can be recognized" (as quoted by Megalakaki et al. 2016, 1632). Furthermore, the ISO method for testing perceptual quality (ISO 9186-2:2008(E)) emphasizes that before the meaning of a symbol can be understood its elements must be identifiable. Pictogram visibility is thus understood as a distinct feature of comprehension and a precondition for comprehension that should be tested independently.

A similar understanding can be perceived in research on warning design, where the legibility of pictorial symbols is comprehended as "the degree of initial clarity of the warning" (Wogalter, Conzola, and Smith-Jackson 2002, 223). Also in this context, it is stressed that before a warning can be understood it must be legible. Hence, Wogalter, Conzola, and Smith-Jackson (2002) differentiate between two stages: First, the early stage that implies the recognition of a shape, i.e. legibility; second, the later stage, i.e. comprehensibility, that implies the understanding of the meaning of a pictogram (or text). Color, size, viewing distance, figure-background contrast, shape, print quality, environment and lighting conditions are approved as influencing factors of legibility (see Kovačević, Brozović, and Bota 2014, Wogalter, Conzola, and Smith-Jackson 2002).

Finally, in the design field, too, there is an equivalent understanding. The notable Japanese pictogram designer, Yukio Ota, who authored the classic *Pictogram Design*, defines a *pictogram* as "a type of graphic symbol" whose purpose is to make "people understand its meaning through the use of a form expressing its meaning" (Ota 1987, 18). By emphasizing *form* in his definition, Ota stresses the importance, not only of comprehension, but also of issues such as visual clarity and legibility. Similarly, Carla Spinillo argues that the effectiveness of pictograms does not only depend on how well they are comprehended but also on how we perceive what is depicted (Spinillo 2012, 3400).

The way the eye decodes the information it sees can be modelled through frequency channels. When we read, the eye selects only one channel depending on the size (Ahrens and Mugikura 2014, 29). Hence, at large visual angles our perceptual system draws on high frequency elements of finer details, while at small visual angles the system draws on the low frequency elements of stroke thickness and proportions. By blurring the image one can see the effect of low frequency channels, as the identification of finer details is disturbed. This information is thus important for the way we see small-sized pictograms, whereas for large-sized pictograms the details become more important (see also the example, although with letters,

in Majaj et al. 2002, 1166). In Figure 7 it becomes clear that while the details and thin strokes in the USP pictograms tend to blend together in small sizes – looking at the pill, for instance – they may be easier to comprehend in larger sizes where all the contextual clues are visible. The Danish icons, on the other hand, are visually less detailed, thus clearer in smaller sizes; however, the lack of contextual clues – such as a hand and a face – may interfere with comprehension.

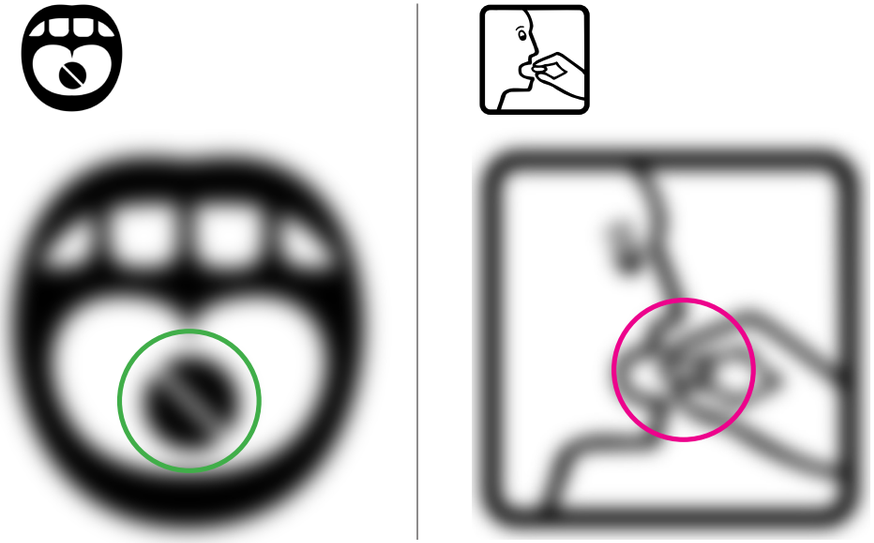


Figure 7

A way of locating potential visibility issues can be achieved by blurring pictograms. In the example above, the pill in the USP pictogram at left is indistinguishable compared to the pill in the Danish icon at right which is clearer.

Source: DLI and USPC

This issue was also noticed by Lesch et al. (2013, 1278) who argue that when we add details and complexity, and the symbol or pictogram is reduced in size, legibility may decrease, which is an important issue particularly for older people.

In summary, legibility concerns both visibility and familiarity and should be tested as a distinct feature from comprehensibility. The visual properties that influence pictogram legibility are for example color, size, contrast, stroke, shape and style. Legibility furthermore depends on the context in which it is shown (medium, distance, luminance, reflection) and the person who sees it (eye maturity and vision) (Kovačević, Brozović, and Bota 2014, Wogalter, Conzola, and Smith-Jackson 2002, Megalakaki et al. 2016).

Review of pictorial legibility research

Pharmaceutical pictograms

The aforementioned issues of visibility and legibility have hardly been addressed in research into pharmaceutical pictograms. As stated earlier, one reason may be that some researchers understand legibility as comprehensibility (e.g. Soares 2013, Kanji, Xu, and Cavaco 2018, Ringseis and Caird 1995, Pires, Vigário, and Cavaco 2016). For instance, Soares (2013) investigated the legibility of USP pictograms for pharmacy clients in Portugal. However, the study appears to concentrate on how the pictograms were understood and not on factors related to the present understanding of legibility, these being size and contrast – or other factors that influence the early stages of information processing. The same applies to a study by Ringseis and Caird (1995), where legibility was mentioned as important but was not tested as a feature distinct from comprehension. In the pre-testing and also the re-testing of 20 pharmaceutical pictograms, legibility and comprehension were examined as a united feature.

In the UK, while examining interpretation differences between American and South African versions of USP pictograms, Knapp et al. (2005) tested two sizes of pictograms (3x3 cm and 9x9 cm). Looking back at Figure 2, one can get a notion of the difference between pictograms of 9x9 cm and 3x3 cm. Not surprisingly they found that large pictograms performed considerable better, and that smaller pictograms could cause additional problems for patients. Given that correct interpretation percentages were halved in many of the smaller versions, Knapp et al. proposed using very simple images to facilitate comprehension of small images (ibid, p. 1231).

Other pictogram related domains

Since legibility is undervalued in studies of pharmaceutical pictograms, the need is there to start layering a research foundation. In that connection it is nessecary to consider related domains that have examined the influence of relevant visual features such as color, size, shape and complexity. Similarly to letterform research, the research domains mentioned forthcoming point to relevant focus areas and research methods that could clarify how to assess the legibility of pharmaceutical pictograms.

The issue of visibility and legibility of graphic symbols has been studied in several domains relating to warning design (e.g. Bzostek and Wogalter 1999, Shieh and Huang 2004, Murray et al. 1998, Shieh and Huang 2003), packaging (e.g. Kovačević, Brozović, and Bota 2014) and traffic signage (e.g. Kline et al. 1990, Long and Kearns 1996, Paulo and Correia 2008, Siswandari and Xiong 2015). This research has given insights about color, visibility distance, shape and slashes. Some studies are preference ratings rather than studies of visual perception (e.g. Shieh and Huang 2003, Murray et al. 1998), but are still mentioned in this context to illustrate the different visual elements or features that are considered important.

One such visual feature is color, which is known to help attract attention and communicate different concepts and levels of hazard. Kovačević, Brozović, and Bota (2014) examined how different illuminants and different colored packaging affect the legibility of pictograms. Pictograms were drawn with lines in five different thicknesses, and to avoid subjectivity scores were assigned according to how many different thick lines were identified without a time limit. Background color proved to affect pictogram legibility the most; the highest performance was on a yellow background and the lowest on a blue one. Furthermore, illuminants simulating typical home lighting increased legibility compared to outdoor simulations. Considering the mentioned research on typeface legibility (i.e. Figure 6) – using pictograms with different line thicknesses and levels of complexity – it could be argued that because the study included too many visual features, it was not possible to decide how they affected the results.

Studies of traffic signs have confirmed some benefits of pictures by showing that icon signs are more visible than text signs (Kline et al. 1990, Schieber and Kline 1994, Long and Kearns 1996). Kline et al (1990) tested the visibility distance of highway signs for drivers of different ages under different lighting conditions. They found that there were no differences in age regarding comprehension, but that icon signs were visible from greater distances than text signs, even further at dusk (Kline et al. 1990). Of particular interest in the present context is the investigation by Kline and Fuchs (1993), who studied how the visibility of symbolic highway signs could be increased by altering their shape. As outlined earlier, in Figure 7, they identified difficult details using an optical filtering approach. The high spatial frequency information contained in each symbol was filtered with the help of an appropriate lens. These details were then redesigned by altering the contour size and increasing the contour separation. In other words, the improved symbols had larger negative spaces and their shapes were more pronounced (see Kline and Fuchs 1993, 28). Interestingly, the advantage of the improved signs proved to be greater for older drivers in three of four tested symbols. This illustrates that working with shapes in detail can provide useful knowledge about visibility.

A number of other studies have concentrated on surround shapes (e.g. Paulo and Correia 2008, Yu, Chan, and Salvendy 2004) and the circle-slash (e.g. Murray et al. 1998). Shieh and Huang (2003) studied the effect of pictorial solidity, size, orientation and thickness of the red circle slash for prohibitive symbols (for a review of these features see pp. 581-83). Their results indicate that the proper pictorial size is 75% of the inner diameter of the slash. They also found that people prefer solid pictorials over those in outline, which fits with the recommendation in the ISO guideline (ISO 22727:2007). The same authors examined the effects of pictorial size and thickness of the red circle slash on glance legibility under degraded conditions (Shieh and Huang 2004). Their findings indicate that such conditions, i.e. reductions of luminance contrast or limited exposure time, small pictorial size and the thickness of circle slashes affect glance legibility.

In letterform research, short exposure time is a method often used, when the focus is to measure the legibility of single letters or numbers (Beier and Dyson 2014, 84), or when the focus is on reading at a glance (e.g. Dobres et al. 2014). Wogalter et al. (2002) used such a short visual exposure method to measure the glance legibility of four variants of circle slashes: over, under, partial and translucent slash. Comprehension scores proved higher for simple symbols representing familiar and concrete concepts and lower for symbols with more detail. Of the four slash variants, comprehension scores were found to be higher for the under and translucent slash. In general, as pointed out by Wogalter et al. (2002), there are some conflicts between the findings in these kinds of studies, most probably due to differences in speed presentations, depiction, circumstances etc. Either way, the findings by Wogalter et al. (2002) suggest that visual complexity may have a negative impact on legibility and hence on comprehension.

Complexity as opposed to legibility and comprehensibility

Complexity is often understood as a negative aspect in terms of the effectiveness of pictograms (e.g. Spinillo 2012, 3399, Byrne 1993). According to the reviews by Houts et al. (2006) and by Dowse and Ehlers (1998), simple realistic pictures without irrelevant details seem to facilitate comprehension more than photographs and more complex pictures. For icons designed for computer interfaces, visual complexity is also known to increase visual search times, because it takes longer to process the information (McDougall, de Bruijn, and Curry 2000, Byrne 1993).

In contrast, other studies have found that when complexity is increased in the form of contextual clues, comprehension is improved compared to simple graphic symbols with fewer clues (Lesch et al. 2013, Zender and Mejía 2013). This was also suggested in a different type of study where participatory design approaches were used to revise and improve different existing pharmaceutical pictograms on smart phones (Wolpin et al. 2016). Based on feedback from low-literate participants, the revised versions were richer in contextual clues and visually less crowded.

An example taken from a comprehension experiment further demonstrates the question of complexity and clues in the context of pharmaceutical pictograms. Wolff and Wogalter (1993) were the first to test the USP pictograms. Back then the collection comprised 30 pictograms of which 28 were tested by asking participants to write the meaning of the pictograms. One of the pictograms that failed was the 'Do not store near heat or in sunlight'. The redesigned version of the pictogram proved successful in tests (see Wolff and Wogalter 1993, 189); however, it has never been implemented in practice. Compared to the current version, Wolff and Wogalter's test version has a clearer slash and is richer in contextual clues (pill glass in separate frame, pictogram radiator, window and sun) to aid comprehension (*Figure 8*). However, the thin white spaces between in window will bleed out in smaller sizes. Similarly, the sun beams and the heat lines will clutter

in smaller sizes. Finally, the use of a separate frame enlarges the size of the pictogram which will further lower legibility in situations where space is important. Increased comprehension can be achieved by adding details (*as was also shown in Figure 7*); however, we need to know more about how this

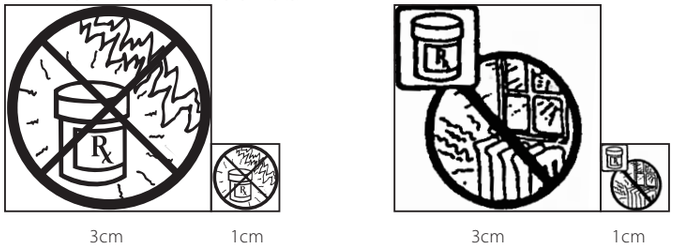


FIGURE 8

Two versions of the 'Do not store near heat or in sunlight' pictogram. (left) The current USP version that failed the comprehension test; (right) Wolf & Wogalter's redesigned and enhanced comprehension version. Displayed here with the permission of Mike Wogalter.

Source: USPC and Wolff and Wogalter (1993)

In this context it is relevant to discuss the relationship between concreteness and complexity. Although the studies mentioned forthcoming are based on icons used in various contexts (e.g. electrical equipment, public information systems and computer interfaces) – very different from pharmaceutical pictograms – they are still considered relevant because they indicate an overall relationship between characteristics. The concreteness of icons is understood as the degree to which an icon represents objects that are familiar to people (McDougall, de Bruijn, and Curry 2000, 291). According to McDougall, de Bruijn, and Curry (2000, 292) some studies have mistakenly coupled concreteness and complexity, without controlling the level of complexity. In these studies, the concrete icons that were used were more complex than the abstract icons, thus leading to the conclusion that for an icon to be concrete, details must be added (the studies McDougall, de Bruijn, and Curry refer to are: Arend, Muthig, and Wandmacher 1987, Green and Barnard 1990, Stammers, George, and Carey 1989).

In contrast, McDougall, Curry, and de Bruijn (1999) examined the relationship between icon concreteness, visual complexity, meaningfulness, familiarity and semantic distance. They found that all characteristics were closely related, with the exception of visual complexity, which was perceived as an independent characteristic. To further investigate whether icon concreteness is dependent on icon complexity or not for user performance, McDougall, de Bruijn, and Curry (2000) conducted a series of experiments in which they controlled concreteness and complexity. They found no relationship between the two and compared to icon concreteness, icon complexity proved to strongly increase visual search time. For the design of icons, McDougall, de Bruijn, and Curry (2000, 304-305) therefore conclude that adding details does not necessarily make icons more concrete and simple icons may also be concrete.

Concluding remarks

The key purpose of this paper has been to highlight legibility as an indispensable factor in the assessment of pharmaceutical pictograms. Based on knowledge primarily from letterform research and by demonstrating some legibility issues in a selection of pharmaceutical pictograms it has been shown that legibility is an important aspect in determining the effectiveness of pictograms. Additionally, the literature review demonstrated that the issue of legibility has historically been neglected, and in order to start creating a research foundation, related domains have to be considered. Through the following concluding remarks, I will summarize why legibility must be prioritized, and – benefiting from the insights from letterform research and related domains – I will provide suggestions for future research.

Legibility must be prioritized

Pharmaceutical pictograms could potentially help to improve the clarity and effectiveness of medicinal information. However, they require additional elements and details to make their meaning understandable and distinguishable for people across age groups, literacy, language and culture. Additionally, before pharmaceutical pictograms can be successfully implemented in leaflets and labels they must meet certain legibility criteria, and here there is a long way to go. We may even question whether it is feasible to apply pharmaceutical pictograms, because of their current poor quality.

Size is a significant feature in legibility and is even more pronounced in detailed and complex pictograms such as pharmaceutical pictograms. While meaningful details may heighten comprehensibility, they appear to lower legibility, particularly when down-scaled to implementable sizes. The current USP pictograms, for instance, have caused problems in smaller sizes (Knapp et al. 2005). This was confirmed through the examples in Figure 7 and 8 where details bleed out in small sizes and thus become difficult to identify.

According to the ISO method for testing perceptual quality (ISO 9186-2:2008), pictograms should be tested in minimum two sizes, the large size to determine whether test participants identify the elements as intended by the designer, the smaller size to determine whether the elements are recognizable. If there is a tendency to test pictograms in too large sizes (as pointed by Knapp et al. 2005, 1228), then the comprehension of these pictograms is less affected by their visibility. Furthermore, with reference to the blurring filter employed in Figure 7, visualizing low frequency channels, it means that we know very little about how we see and thus comprehend pictograms in implementable sizes. In this context, it should be mentioned that the large test size employed by Knapp et al. (2005) is 9x9 cm, which is larger than the largest size recommended by ISO (i.e. 8x8 cm). This emphasizes the need to also design and test pictograms in smaller sizes.

Moreover, by looking at the ISO design guidelines for graphic symbols (ISO 22727:2007) and analyzing a selection of pictograms, we have seen that the specific recommendations regarding line width, size and outline are not necessarily followed. In this connection there appears to be no standard way of designing pharmaceutical pictograms from one country to another. One reason for these shortcomings may be that the design guidelines do not fit pictograms with a more complex character. Another reason may be that the ISO symbol platform (OBP) does not include pharmaceutical pictograms. Yet another reason may be that the design field to date has not entered this area. The point is that it is not always clear how and where pharmaceutical pictograms are implemented in the test material.

According to Beier and Dyson (2014) many typeface legibility researchers appear to have a scientific background but lack a typographic understanding. The same tendency can be observed in research on pharmaceutical pictograms. Some comprehension studies, for instance, indicate that simple and large pictograms help the elderly (Knapp et al. 2005, Berthenet, Vaillancourt, and Pouliot 2016). While this makes sense, we need to know more specifically what this means visually. What do we mean by simplicity in this particular context? Are we talking about the skeleton length, the number of elements, the contour of the image or the white spaces? And how are these affected in different sizes and reading situations?

Elderly people are an important group when it comes to medicine information. The fact that visual ability is known to decline by age (Ng, Chan, and Ho 2017, 168) highlights legibility as a crucial factor. In a number of fields, e.g. warning design, typography, psychology and design, legibility is understood as a feature distinct from comprehension, where features such as color, size contrast etc. indeed are recognized as important. While these fields have shown that legibility is a precondition for comprehensibility, there is no focus on this aspect in the design and testing of pharmaceutical pictograms. Legibility research is here almost non-existing. Thus there is a need to determine the components that increase legibility in order to improve the effectiveness of pharmaceutical pictograms and based on this formulate customized guidelines.

Suggestions for future research

From letterform research we are well aware of the importance of controlling the different parameters concerned: first, that a distinction can be made between visibility and familiarity; second, that the different visual variables at stake such as size, contrast, stroke etc. must be isolated in order to assess their influence on performance. Research from other related domains furthermore draws attention to relevant elements of graphic symbols specifically, such as surround shape versus pictogram size and circle slash, and points to ways of altering the visibility of pictograms. As mentioned, Kline and Fuchs (1993) improved the visibility of road signs by redesigning the problematic elements that were defined and found the advantage to be greater among older drivers. This way of working may be a step forward in the context of pharmaceutical pictograms, followed by comprehensive prototyping and testing.

However, before we can start measuring the different visual dimensions of pictograms in detail, we need to figure out how to test the

visibility of pictograms compared to letters and words. The alphabet is limited to a specific number of letters, and we can all agree, when visible, that an *n* is an *n*. The same is not necessarily the case for pictures. They vary so much in shape and form and the number of pictures is unlimited, which makes the comparison far from straightforward. The latter probably presents one of the main challenges. Educated people are familiar with the alphabet; however, all people are not familiar with all pictures. An experimental setting should therefore account for this in a way that does not interfere with the results. A way to control familiarity could be to present all the chosen stimuli beforehand and use multiple choice assessments with a list of pictograms or words. When it comes to variations of shape and form, one should ensure, when designing or choosing pictograms for such experiments, that they are comparable by determining their resemblance, i.e. stroke width, complexity, size, etc. This is where the knowledge of the designer becomes relevant and why future research should focus on incorporating design knowledge into experiments. Based on his/her experience with form, a designer can both recognize the different variables at stake and understand how to isolate these variables when designing test material. Thus a design-oriented approach could bring new knowledge about different components and how they may increase legibility.

Some final points

Finally, to underline the point, there are still many pictograms that fail to meet the ISO or ANSI comprehension criteria and what happens when every country develops its own set of pictograms in a world where boundaries are becoming increasingly fluid? Should there be some kind of standard in this field too? Even though standardizing can be problematic, the tendency towards using pictograms in medical contexts does call for comprehensive and customized guidelines developed for pharmaceutical pictograms. Such guidelines should also be incorporated into international and national pharmaceutical guidelines for example those issued by the European Commission. As such, a better understanding of the visual features that constitute legibility is a big step forward to make legibility and comprehension go hand in hand, as well as to create customized guidelines. In so doing we will be able to further explore the benefits of pictograms in pharmaceutical leaflets and labels and to meet ISO and ANSI success criteria.

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