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Pia Pedersen, Chiron Oderkerk & Sofie Beier

Simplification of pharmaceutical pictograms to improve visual acuity

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The purpose of pharmaceutical pictograms is to help patients manage their medicinal treatment. However, the pictograms often lack perceptual clarity. While they are frequently tested for aspects such as comprehension, little attention has been paid to their legibility. This paper presents the conception and results of an experiment adapted from the ISO 'Method for testing perceptual quality' (ISO 9186-2:2008) to measure the visibility of pictogram elements in two sets: 15 American USP pictograms and 15 redesigned versions reduced in complexity. The statistical analysis did not show reliable significant differences, which indicates that there are more factors at stake.

1. Introduction

Many medical patients find it difficult to take in medicinal information because of their mental state or the technical terminology used in patient information leaflets (Houts et al., 2006, p. 174). Some patients are particularly vulnerable in this context, such as illiterate persons and non-native speakers. Another essential group is the elderly, many of whom suffer from low vision or cognitive decline and who represent a growing population that faces increasingly complex drug regimens. The growing number of medical prescriptions has generated interest in the design of simple pictures, such as pictograms, in order to help patients manage their medicinal treatment (Choi, 2011; Del Re et al., 2016; Dowse, 2021; Kanji et al., 2018; Vaillancourt et al., 2019). Medication errors are a universal concern and can cause harm to patients, even death. Furthermore, it has been shown that the error rate increases with the number of medicines prescribed (WHO, 2019, p. 15). As the number of people who take prescribed medication increases, patients are given increasing responsibility for managing their medication.

1.1 Medicine leaflets

Within the EU, all medicine packaging is required to include information in the form of leaflets (Directive 92/27/EEC, 1992). The content and design of these leaflets and their packaging are bound by European legislation and guidelines (Waarde, 2017). Nonetheless, there is a consensus across research disciplines that the legislation and guidelines—in contrary to their purpose—obstruct the user-friendly design and development of medical information (Askehave & Zethsen, 2014; Dickinson & Gallina, 2017; Pander Maat & Lentz, 2010; Waarde, 2008, 2010, 2017; Waarde & Spinillo, 2015).

The use of pictograms for medical information, often referred to as pharmaceutical pictograms, is permitted, though still limited (Kanji, Xu, and Cavaco 2018). However, pharmaceutical pictograms could be an effective tool; previous research suggests that pictograms can enhance patients' ability to notice, understand, recall, and adhere to information about their medicinal treatment (Barros et al., 2014; Choi, 2011; Del Re et al., 2016; Dowse & Ehlers, 1998; Houts et al., 2006; Katz et al., 2006).

1.2 Legibility versus comprehension

Research into pharmaceutical pictograms and other health-related pictograms is typically oriented towards comprehension, specifically, with regard to the selection of relevant pictogram components (e.g. Korenevsky et al., 2013; Strauss & Zender, 2017; Zender & Mejía, 2013), health literacy (e.g. Hill, 2006; Sharif et al., 2014), and older adults (e.g. Choi, 2011; Knapp et al., 2005; Lesch et al., 2013). When it comes to issues of pictogram legibility (i.e., the ability to differentiate and identify the elements of a pictogram), these are rarely prioritized in theory, nor in practice (Pedersen, 2019). Pictogram legibility is an underexplored, yet essential, area within pictogram research, as legibility is a precondition for comprehensibility (Boersema & Adams, 2017; Pedersen, 2019; Wogalter, Conzola, et al., 2002).

Pharmaceutical pictograms are often complex because of the complicated and closely related nature of the concepts they convey. Additional contextual details are needed to make the pictograms clear and differentiable. Increased pictogram complexity has been shown to improve comprehension compared to simpler pictograms with fewer clues (Lesch et al., 2013; Zender & Mejía, 2013). On the other hand, if the pictograms are downscaled to fit on e.g., patient leaflets, details may blend and decrease legibility (Pedersen, 2019, p. 75–76).

1.3 Visual complexity

Research into warning signs and pictorial safety systems suggests that visual complexity may hamper the ability to identify images (Wogalter, La Murray, et al., 2002). However, in the context of pharmaceutical pictograms, this has yet to be shown. One of the best-researched libraries of pharmaceutical pictograms is the USP (The United States Pharmacopeia) introduced by The United States Pharmacopeia Dispensing Information (USP-DI).

A study examining the differences in interpretation between American and South African versions of USP pictograms—tested in 3 × 3 cm and 9 × 9 cm—showed that correct interpretation rates were halved in many of the smaller versions (Knapp et al., 2005); which suggests that pharmaceutical pictograms tested only at large sizes fail to capture the influence of lowered visibility on the comprehension of small pictograms. To determine the visual features that increase visual acuity (i.e., the minimum visual angle required by an observer in order to discern details of a pictogram (Zhang et al., 2007)), and thus improve the effectiveness of pharmaceutical pictograms at the size at which they will be seen in real-life usage, it is necessary to design and test pictograms in smaller sizes. On the basis of their findings, Knapp et al. suggested that simple images could improve the comprehension of small images (Knapp et al., 2005, p. 1231).

1.4 Crowding

There is a general consensus within the field of vision research that not only poor visual acuity but also the effect of crowding has a diminishing effect on object recognition (Lalor et al., 2016; Legge et al., 2007). Crowding is known as a phenomenon that results in the perceptual merging of objects in proximity to one another (Bouma, 1970). It is often conceptualised as being dependent on the spacing between objects being less

than or equal to the 'critical spacing' at which crowding will occur. However, it has likewise been suggested that crowding is determined by the critical spacing between the features of the objects, as crowding has been shown to be modulated by the location of features within objects, despite constant object spacing (Rosen et al., 2014). To minimize effects of crowding between elements within each pictogram, pictograms that need to work in small sizes would likely benefit from being designed with their strokes placed further apart. Pictograms that were redesigned to maximize both the spacing between the elements that comprise the pictogram and the size of the individual elements were shown to be recognizable at a longer viewing distance than their unaltered counterparts (Kline & Fuchs, 1993).

The aim of the present study was to investigate the balance between details and simplification of shapes. Guided by findings on letter recognition that showed that simple letters are more easily recognized than complex letters (Beier et al., 2018; Bernard & Chung, 2011; Pelli et al., 2006), we hypothesised that simplifying the shapes, while maintaining the same level of details, would improve the legibility of pharmaceutical pictograms.

As pictogram legibility has received little attention within the research literature, and for that reason little is known of the methodology and theory, this paper takes an exploratory approach in identifying methodologies that fit the research question of how to measure the effect of stroke complexity of pictograms at the limit of visual acuity. We hypothesesed that reduced complexity and crowding would improve visual acuity and accuracy in recognizing elements within each pictogram. Our experimental approach involves aspects of individual assessment in the scoring of responses and quantitative data analysis. The implications of this new approach to pictogram legibility research will be addressed in the discussion.

2. Experiment

We were interested in examining how the length of a pictogram skeleton influences the visibility of its elements. We did so by measuring the visual acuity and accuracy of two sets of pictograms in a between-respondents experimental paradigm.

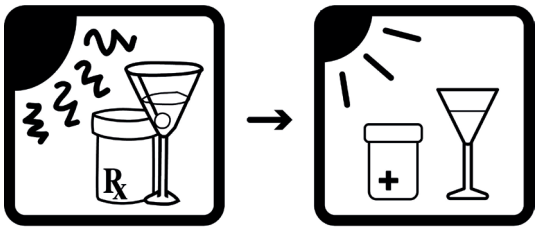
2.1 Respondents

The experiment included 75 respondents, aged from 19 to 34 years (mean age = 22.5 years, SD = 2.94 years, 54 women) with self-reported normal or corrected-to-normal vision. All respondents were students at the Institute of Visual Design at The Royal Danish Academy and the folk high school Hadsten Højskole. The respondents did not receive credits for their participation. The experiment was conducted over three sessions between May 2019 and February 2020 and followed the rules of the Declaration of Helsinki and The Danish Code of Conduct for Research Integrity.

2.2 Stimuli

Two pictogram versions were tested: (1) 15 United States Pharmacopeia (USP) pictograms with particularly complex skeleton structures, and (2) 15 redesigned versions in which the skeleton length was shortened and simplified. To identify the level of complexity of each pictogram, we adapted a methodology of measuring the perimetric complexity values, which is defined as the square of the inside-and-outside perimeter of a symbol divided by the 'ink' area (Bernard & Chung, 2011), see Figure 1. The USP pictograms were chosen because they represent a large set of easily accessible pictograms frequently found in the research literature (see also Dowse, 2021, p. 1212).

Figure 1. Measuring the level of complexity. The length of a pictogram's morphological skeleton defined its complexity, hence the longer the pictogram the greater its complexity. The white line inside the two pictogram elements above illustrates the skeleton



Mantained features
· frame
· stroke weight
· filled areas
· referents
· visual hiearchy

Modified features
· form
· white space
· element size
· perspective
· culture-bound symbols

Figure 2. Redesign principles for simplifying the pictogram skeletons

The visual simplification of the redesigned pictograms was guided by a set of predetermined principles, see Figure 2. Under normal circumstances, when a symbol is submitted for ISO approval, it must follow the relevant ISO design principles and criteria (ISO 9186-2:2008, 2008, p. 3). However, the USP pictograms do not follow the ISO standards (see example revealing too-thin stroke weights in Pedersen 2019, Figure 5, p. 80). To ensure that the two versions would be comparable (Pedersen 2019, p. 81), certain visual features of the USP pictograms were maintained in the redesigned pictograms: frame, stroke weight, filled areas and surfaces, referents, and overall visual hierarchy (organization of the relationship between elements within the frame). Other features, such as form, white space, element size, perspective, and culturally specific symbols, were modified and simplified. We were not interested in the specific effect of each of these features but, rather, chose features that would shorten the pictogram skeleton while maintaining the referents and their meaning.

In the 'heart' and 'intestine' pictograms, for instance, the fingers and other details in the body shape were straightened out in the redesigned versions. The body shape was thus smoothened to reduce noise, while the overall visuals were maintained. If the use of space could be improved, white space would be added between elements or elements might be given a slight change of size and position. In the redesigned version of the 'alcohol' pictogram, as the perspective was removed and the size of the glasses slightly reduced, it was possible to separate the three glasses in an attempt to reduce the effect of crowding.

In the redesign, it was thus crucial to ensure that a scorable element could not change referent or be attributed a different meaning. The 'freeze' pictogram would presumably be easier to comprehend with a snowflake symbol in the freezer, as the freezer alone resembles a closet and does not convey the intended meaning. Such a change, however, goes beyond the scope of testing the identifiability of the elements. Exceptionally, two

NAME	ORIGINAL	REDESIGN	ELEMENTS	CHANGES
heat	 PC =1300.37	 PC = 848.16	heat 1 heat 2 medicine jar	line shape perspective detail reduction symbol
child reach	 PC =1027.11	 PC = 888.00	child/baby table/chair shelf grocery	line shape perspective
medicines	 PC =1671.65	 PC =1331.97	pills pipette medicine bottle medicine jar black medicine jar	perspective shape symbol
cheese	 PC = 1031.58	 PC = 989.99	cheese milk carton	perspective shape detail reduction
alcohol	 PC = 1354.09	 PC = 1108.23	wine glass beer glass cocktail glass	perspective shape detail reduction space
freeze	 PC =1073.63	 PC = 796.11	freezer glass/tub	perspective shape detail reduction
refrigerate	 PC = 1175.41	 PC = 920.59	fridge content/groceries	perspective shape detail reduction
blood pressure	 PC = 1110.98	 PC = 1078.51	person blood pressure cuff arrow chronometer/clock	line shape position size
injection	 PC = 777.63	 PC = 519.12	syringe	perspective detail reduction
suppository	 PC = 1072.38	 PC = 704.90	arrow arrow suppository packaging	perspective shape detail reduction
milk glass	 PC = 1193.49	 PC = 1125.67	glass of milk milk carton	perspective shape detail reduction space
heart	 PC = 1210.87	 PC = 919.02	upper body heart ECG line	line shape size
intestine	 PC = 1668.92	 PC = 1299.31	upper body intestine	line shape
read label	 PC = 1082.70	 PC = 656.82	face arrow hand medicine jar	perspective shape detail reduction space symbol
medical alert	 PC = 1459.62	 PC = 1199.37	hand medical bracelet medical symbol	shape position symbol

PC = Measured perimetric complexity

Figure 3. The two sets of pictograms with their respective scorable elements and changes listed. If the original USP versions contained additional features, that is, negation marks or additional pictograms (from combined pictograms), these were removed to maintain focus solely on the pictogram skeletons. Six USP pictograms did not print well in small sizes, probably because they had vector points from an old picture streamline and consequently needed to be redrawn

medicine-related symbols were changed to fit European standards while their visual complexity was also lowered. In the 'heat', 'medicines', and 'read label' pictograms, the 'R_x', which is an abbreviation for medical prescriptions, was changed to a '+', which is often employed for 'medical' in Europe. In the 'medical alert' pictogram, the 'Caduceus' (with two snakes and wings) in the 'star of life' was changed to the 'Rod of Asclepius' (with a single snake).

2.3 Procedure

In the between-respondents design, the experiment was based on the ISO (International Organization for Standardization) 'Method for testing perceptual quality' of graphical symbols (ISO 9186-2:2008, 2008). The key principle of the ISO standard method is to show symbols to respondents and ask them to identify and describe their different elements. Our experiment follows the ISO method's guidelines for apparatus, test material, respondents, and scoring, but differs in the way different sizes were tested and in the presentation of results (discussed in the Results section). According to the ISO test method, symbols should be assessed in at least two sizes; the large size (8 × 8 cm at 2 metres' viewing distance) helps decide whether depicted elements are named as intended, and the small sizes determine whether elements are recognizable at smaller visual angles. In this experiment, we were not interested

in testing how symbols work in one specific small size, but in how the critical size is affected by skeleton length, that is, how small the pictogram can be and still be identifiable. Therefore, instead of testing only one pictogram size per respondent group—as is otherwise done in the ISO method (ISO 9186-2:2008, 2008, p. 4)—each respondent was presented with five different sizes of the same pictogram.

To familiarize respondents with the format, the experiment began with a thorough introduction to the test. Respondents were not familiar with the pictograms or well-informed about their relation to medical information. The visual acuity of the respondents was initially estimated using a standard test, the Landolt 'c' chart. The experiment included two printed documents, one displaying the pictograms, which was placed on the floor, and an answer sheet, which was placed on a table. Respondents saw one printed sheet at a time, each sheet showing five different pictograms, presented in identical stimulus print size. Respondents were allowed to take as much time as they needed to identify and name the elements they saw in the pictograms.

The stimuli were ordered in the sequence of presentation with 30 different orders, each of which was shown to at least two respondents. Each pictogram stimulus was first presented in the smallest size. After a respondent had attempted to identify all pictograms of the smallest size, they would be presented with the same pictograms again, in the same order but in a larger size. In order to measure the effect of pictogram size on recognition, we increased the size of the pictograms logarithmically four times by a factor of 1.5, starting with the smallest pictogram at print size 0.45 cm. During each sequence, the version of the pictograms would alternate between one pictogram and the next, so that participants would continually be presented with the USP version of a pictogram followed by the redesigned version of the following pictogram, or vice versa. Thus, all the respondents would be exposed to some of the pictograms in the USP version, and to some in the redesigned version.

The task was to identify the individual elements of the pictogram. Respondents were asked to either identify the visual features (e.g., bottle with name tag) or to name the object (e.g., pill bottle). Based on the methodology employed in ophthalmologic acuity charts, we used the logarithmically increasing pictogram sizes to determine the minimum pictogram size required to identify visual elements in the pictograms (see recognition acuity 3.2; Radner, 2017). The viewing distance to the test material was maintained using a specific sitting position. Respondents were given instructions to sit with their legs slightly apart, thighs parallel to the floor, and to maintain the same viewing distance by placing their elbows on their thighs while resting their heads on their fists (Figure 4). Furthermore, respondents were instructed to look away when they turned to the next page. The experiment was carried out in an office environment,

Figure 4. Respondents' sitting position during the experiment: Legs slightly apart, elbows resting on their thighs, and head resting on their fists

and the pictograms were printed on paper in high quality (Printer: Konica Minolta Bizhub Press C 1070. Paper: Colour Copy 200 g, no. 88008638 from Papyrus).

3. Results

3.1 Scoring system

Following the ISO method (ISO 9186-2:2008, 2008: 5–6), a list of elements and accurate descriptions was created for each pictogram. In creating the list, we first determined what constitutes a key element in each pictogram, and second, when an element's description is correct (for the detailed list and scoring system, see **Appendix)**. These elements formed the basis for the scoring system and statistical analysis. When an element was correctly described by a respondent, it scored one point. If the respondent provided additional details about the same element in subsequent responses, no additional points were given. All correct answers were transcribed.

The scoring system was adjusted based on two pilot experiments and, in the case of a few pictogram elements, over the course of the scoring procedure. There was considerable grey area in determining how accurate an answer needed to be in order to be considered correct. Uncertainties often pertained to the level of detailing regarding medical symbols within pictograms, such as the 'star of life' and the R_x. Uncertainties also occurred when considering more abstract elements, such as the suppository, which was often described by its shape or through a resembling object. When there was doubt about the correctness of an answer, the answer was marked and validated afterwards by examining all respondents' answers in relation to the same pictogram. Sometimes, this would lead to a minor adjustment or to further specification of the rules. As recommended, the scoring and analysis of answers were performed by one jury (ISO 9186-2:2008, 2008, p. 5).

3.2 Data analysis

To investigate whether legibility had improved in the redesigned pictograms at small and larger sizes, we analysed their recognition accuracy and recognition acuity. Recognition *accuracy* measured how many elements of a pictogram could be correctly identified when presented at the largest size defined as the percentage of correct reports. Recognition *acuity* was a measure of the minimum size required to correctly identify at least one element in a pictogram, and it ranged from 1 to 5, with 1 being the best possible rank indicating the participant was able to identify an element at the smallest size.

For both measures, we compared the redesigned and the USP versions of each pictogram separately, using a series of Mann-Whitney *U* tests as between-subjects analyses. The Mann-Whitney U test does not compare the means of the values of the dependent variables. Instead, the Mann-Whitney U test ranks all values from low to high before comparing the mean ranks of the ranked values. We applied the conservative Bonferroni correction to guard against type 1 errors, such that significance level α was set to .05/15 = .003.

3.3 Recognition accuracy

Statistical analysis of the effect of the redesign of the pictograms on recognition accuracy did not yield statistically reliable overall results. This was because we violated the assumption of homogeneity of variance in all cases that showed significant differences in recognition accuracy; these being the 'heat', 'alcohol', and 'medical alert' pictograms. Specifically, the non-parametric median-based Levene's tests for equality of variances showed significant differences between the variances of the percentage of correct reports for the redesigned and USP versions of the 'heat', 'alcohol', and 'medical alert'

pictograms (all p's < .018), and tended towards significance for 'medicines' (p = .056). The Mann-Whitney U test is vulnerable to violations of the assumption of homogeneity of variance, resulting in an increased likelihood of type 1 errors. Thus significant differences found in the mean ranks of recognition accuracy percentages must be assumed to be spurious when found congruently with violations of homogeneity of variance, as is the case for the 'heat', 'alcohol' and 'medical alert' pictograms. Descriptive statistics and results for the recognition accuracy can be found in Table 1. Furthermore, participants were able to recognise nearly all elements of both the Redesigned and the USP versions of the 'cheese', 'suppository', and 'milk glass' pictograms. As a result of these ceiling effects, the accuracy percentage was not significantly different between Redesigned and USP for these pictograms.

3.4 Recognition acuity

The non-parametric median-based Levene's tests indicated violations of the assumption of homogeneity of variance for the pictograms 'child reach', 'medicines', and 'cheese' (all p's < .003); such that they could not yield reliable statistical results.

Table 1. Descriptive statistics, Mann-Whitney U tests, and effect sizes of recognition accuracy

Image name	Median accuracy %		Sample size *N*		Mann–Whitney *U*	*p-value*	r_{bo}
	Redesign	Redesign	Redesign	USP			
heat†	100	66.67	39	35	310.5	< .001*	0.55
child reach	75	100	37	37	548.5	= .12	0.20
medicine	100	100	39	35	548.5	= .067	0.20
cheese	100	100	35	39	682.5	> .999	0.00
alcohol†	100	66.67	36	38	337	< .001*	0.51
freeze	100	100	35	39	667.5	= .89	0.02
refrigerate	100	100	36	38	671	= .904	0.02
blood pressure	100	100	38	36	599	= .264	0.12
injection	100	100	34	40	680	> .999	0.00
suppository	75	50	35	39	473	= .018	0.31
milk glass	100	100	36	37	630	= .493	0.05
heart	100	100	38	36	612	= .243	0.11
intestine	100	100	36	38	620	= .437	0.09
read label	75	75	39	35	618	= .466	0.09
medical alert†	100	66.67	40	34	419	< .001*	0.38

Note.

Cross (†). denotes a significant Levene's test

Asterisk (*). denotes significance at α = .0034. Effect sizes were given by the Rank-Biserial correlation *rbo*.

Table 2. Descriptive statistics, Mann-Whitney U tests, and effect sizes of recognition acuity

Image name	Median acuity size		Sample size *n*		Mann–Whitney *U*	*p*-value	r_{bo}
	Redesign	USP	Redesign	USP			
heat	2	3	39	34	276	< .001*	0.58
child reach†	3	3	37	37	660	= .752	0.04
medicine†	3	4	39	35	330	< .001*	0.52
cheese†	3	3	35	39	390	< .001*	0.43
alcohol	2	3	36	38	354	< .001*	0.48
freeze	4	3	33	37	521	= .261	0.15
refrigerate	3	4	36	37	351.5	< .001*	0.47
blood pressure	2.5	2	38	36	596.5	= .299	0.13
injection	2	2	34	40	581	> .999	0.15
suppository	2	3	34	33	353.5	= .007	0.37
milk glass	2	3	37	37	366.5	< .001*	0.46
heart	2	2	38	36	612.5	= .408	0.10
intestine	1	2	36	38	508.5	= .036	0.26
read label	3	2	39	35	650	= .714	0.05
medical alert	2	2	40	34	593.5	= 0.28	0.13

Note.
Cross (†). denotes a significant Levene's test
Asterisk (*). denotes significance at $\alpha = .0034$.
Effect sizes were given by the Rank-Biserial correlation *rbo*.

However, contrary to recognition accuracy, four redesigned pictograms were found to result in significantly lower mean ranks of recognition acuity than the USP pictograms, without violating the assumption of homogeneity. Specifically, non-parametric *t*-tests showed significant performance differences between participant groups for the pictograms 'alcohol', 'refrigerate', and 'milk glass' with medium effect size, and 'heat' with a large effect size (see Figure 5). Descriptive statistics and results for the recognition acuity can be found in Table 2.

Figure 5. The 'heat', 'alcohol', 'refrigerate', and 'milk' pictograms showed enhanced recognition acuity for the redesigned pictograms

4. Qualitative explorations

4.1 Perimetric complexity

While the purpose of the redesign principles presented in Figure 2 was to reduce perimetric complexity, the statistical analysis did not confirm our hypothesis that lowering perimetric complexity would improve visual acuity in all cases. The highest reduction in perimetric complexity across all 15 pictograms was achieved in the 'read label' pictogram (Figure 6), which, although its perimetric complexity value was 39.33% lower than the original version, it failed to significantly improve performance. The reason for this could be that even though the redesigned pictogram was visually simpler, the simplification did not improve the identification of its elements. One element that might have been oversimplified is the hand, which was cropped in the redesigned version and became as a result less visible. Another element that might have also been oversimplified is the pill glass, which in the redesigned version was sometimes misidentified as a phone.

Of the four pictograms that demonstrated significant improvement of recognition acuity, three had a reduction in perimetric complexity that was either higher than the average or fell within one standard deviation from the average reduction in perimetric complexity across all pictograms (*mean* = 20.22%, *STD* = 11.37%); these being the 'heat' pictogram with a reduction of 34.78%, the 'refrigerate' pictogram with 21.68%, and the 'alcohol' pictogram with 18.16%. Even though the redesigned 'milk' pictogram significantly enhanced recognition acuity, it nevertheless represented one of the smallest reductions in perimetric complexity with 5.68%.

In the redesigned version of the 'milk' pictogram, the perspective was reduced, one of the cows and the word 'milk' were removed, and space was added between the glass and the milk carton. This seems to suggest that space should be added between elements within a pictogram in order to improve visual acuity. In addition, the overlaying of objects should be avoided, even though this may increase perimetric complexity, as uncut shapes need more strokes. The above exploration challenges the notion that a reduction of perimetric complexity necessarily enhances acuity, as different effects of feature visibility and feature recognition are at play.

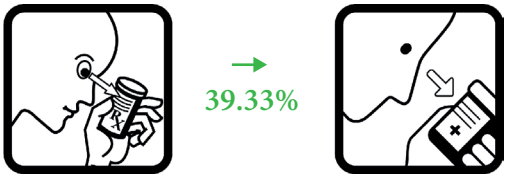


Figure 6. The 'read label' had the strongest perimetric complexity reduction of 39.33%

Figure 7. The 'milk'' pictogram had the lowest perimetric complexity reductions of 5.68%

4.2 Effects of crowding

We expected that one of the key aspects of improving the identification of pharmaceutical pictograms would involve the reduction of crowding. Of the 15 redesigned pictograms, spacing between the elements was increased, thereby reducing the effect of crowding, in the 'alcohol' and the 'heat' pictograms, see Figure 8.

The beer mug in the original version of the 'alcohol' pictogram was often difficult to identify, whereas in the redesigned version it performed better. This could be because the beer mug was no longer crowded by the two glasses, nor by the many details within the beer mug, such as the foam, that blended together. By eliminating the overlap, the handle of the beer mug, which is an important element for its identification, was no longer hidden.

Figure 8. The 'alcohol' and the 'heat' pictograms are examples of pictograms where the distance between lines and objects has been increased. This should reduce effects of crowding

In the original 'heat' pictogram, the sun rays were often difficult to identify and misinterpreted as flashing light, confetti, lightning lines, radioactivity, or an explosion. This was no longer a problem for the redesigned version where the sun rays were presented as four outlined sunbeams.

The reduction of lines and added white space within and around these two pictogram elements (beer mug and sunbeams) made the pictograms simpler, fully visible and, as a result more distinguishable. While the cluttering of objects is apparent, this exploration also points to the importance of designing a shape that captures the essence of its referent.

These observations further indicate that many factors are at play, and while we cannot draw reliable conclusions from the statistical analysis, it is still worth noticing that these two redesigned pictograms, in which the effect of crowding was diminished, enjoyed enhanced recognition at smaller sizes.

5. Discussion

The statistical analysis did not show reliable results that could support the hypothesis that simplification and reduced crowding will improve visual acuity and element identification, and therefore a qualitative exploration of the data was needed. The exploration showed that the strongest reduction of perimetric complexity did not improve performance, while one of the smallest reductions was shown to perform well. This suggests that for performance to be improved several design factors must work together. A visual inspection of the pictograms indicated that supporting design factors could be (1) minimizing the overlaying of objects, (2) reducing the number of strokes within each object, and (3) reducing perspective.

5.1 Identification versus interpretation

While previous findings have demonstrated that decreased perimetric complexity improves digit and letter recognition (Beier et al., 2018; Bernard & Chung, 2011; Pelli et al., 2006), our experiment has not succeeded in demonstrating that the positive effect of stroke simplicity is also evident in pictogram design.

The dominant difference between experiments of letter identification and pictogram identification is that for the experienced reader, letters consist of a familiar set of features (Rosa et al., 2016; Schubert, 2017), that is, the letter 'a' may have multiple variations which the reader will recognize as an 'a' (Beier, 2012). Conversely, pharmaceutical pictograms are often unfamiliar, as they combine visual elements to form new meaning. For instance, the 'child reach' pictogram comprises an infant, a table, a shelf, and some groceries, which all combine to create the meaning: 'where children can reach it'. As one needs to be able to explain what one sees in order to prove that one actually saw it, it is difficult to measure visual acuity and the accuracy of identification of pictograms without also measuring comprehension. Others have dealt with this challenge by having respondents draw the object afterwards (Sayim & Wagemans, 2017), adapting a same-different paradigm (Wong & Szücs, 2013), or employing an alternative forced-choice paradigm (Hamm et al., 2018). Such approaches, however, are difficult to implement in our case due to the complexity and ambiguity of pharmaceutical pictograms.

5.2 Methodological approach and implications of results

Simplifying visual representation is challenging, as one will have to create a shape that is characteristic enough to represent its referent. It is therefore difficult to simplify a representation without testing comprehension. When we redesign elements of a pictogram, it is important to consider the form that characterizes that object. Our experiment demonstrates how difficult it is to test whether the identification of redesigned pictograms has improved.

The chosen methodological approach was based on the ISO Standard, which provides a scoring system that can be used for collecting data.

Great effort was made to standardize our approach. However, due to changes to the ISO Standard, we had some difficulties with regard to ways of cataloging the irregularity of the answers. Sometimes, participants would not write things they had already identified in other answers. Hence, elements that were noticed in smaller sizes were omitted in the answers regarding bigger sizes. In spite of these shortcomings, it is our assessment that the methodology was the best available solution for measuring visual perception of small-sized pictograms that communicate multi-faceted messages.

6. Conclusion

By measuring the visual acuity and accuracy of a set of 15 American USP pharmaceutical pictograms and comparing these with a set of 15 redesigned versions of greater simplicity, our study showed no significant differences between the two sets. Looking at the each individual pictogram, we found that the redesigned versions had more cases where elements could be identified at small sizes compared to the USP versions of the pictograms, which never outperformed the redesigned versions. Our findings also indicated that a low perimetric complexity alone does not improve the legibility of pharmaceutical pictograms, and that many design factors are at play when it comes to the identification of elements in small sizes.

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Appendix

Scoring system (https://bit.ly/3umoW77)

About the authors

Pia Pedersen is an associate professor at the Centre for Visibility Design at the Royal Danish Academy. She has published about pictogram legibility and ISOTYPE including the academic papers: 'Legibility of Pharmaceutical Pictograms: Towards defining a paradigm', 'Behind Isotype Charts: The Design of Number-Fact Pictures' and thePhD thesis 'Beyond Rows of Little Men'.

Email: pipe@kglakademi.dk

Chiron Oderkerk is a postdoctoral researcher at The Royal Danish Academy at the Institute of Visual Design. His research here has focused on font legibility such as in the academic papers: 'The effect of age and font on reading ability' and 'The effect of age and font on reading ability'.

Email: code@kglakademi.dk

Professor WSR **Sofie Beier** is head of Centre for Visibility Design at the Royal Danish Academy. She is the author of the books 'Type Tricks: Your personal guide to type design' and 'Reading Letters: designing for legibility' and has published numerous academic papers on typeface legibility.

Email: sbe@kglakademi.dk