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Well-designed medical pictograms accelerate search

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ABSTRACT

Two types of newly designed pharmaceutical pictograms (with and without context) were compared with an existing type of certified pictograms regarding their *search efficiency*. Each of the 30 participants had to search a total of 1′090 "fictitious" medical shelves for a certain box defined by the amount and type of medical instructions given (memory size) and presented among a variable number of other boxes (set size). The boxes contained the different types of pictograms mentioned above. Calculated factorial analyses on reaction time data, among others, showed that the two newly designed pictogram types make search more efficient compared to existing types of pictograms (i.e., flatter reaction time x set size slopes). Furthermore, regardless of the type of pictogram, this set size effect became more pronounced with larger memory sizes. Overall, the newly designed pictograms need fewer attentional resources and therefore might help to increase patient adherence.

1. Introduction

Not following a physician's instructions regarding the timing, dosage, etc. of medication intake is a phenomenon known as *non-adherence* (Cramer et al., 2008). According to the World Health Organization (WHO) non-adherence is considered a major cause of morbidity, mortality and increased health care costs (Sabaté, 2003). In the USA alone, about 125′000 deaths per year are attributable to non-adherence, resulting in an estimated cost of US $100 billion to US $300 billion per year (DiMatteo, 2004; IMS Institute for Healthcare Informatics, 2013; New England Healthcare Institute, 2009; Sabaté, 2003; Viswanathan et al., 2012).

Causes of non-adherence are mostly identified in the outpatient setting (Bates, 2007; Fallis et al., 2013) where it is the patient's responsibility to appropriately apply the information provided about the medical therapy – for example, through the text-based *package inserts* (Katz et al., 2006). However, the underlying *meaning* of text-based package inserts is difficult to understand for people of all reading skills or *literacy levels*[1] (Houts et al., 2006) due to their complexity (Fuchs et al., 2010), but also due to language barriers for migrants and tourists in general (Montagne, 2013).

One way to tackle this problem is to supplement package inserts with pharmaceutical *pictograms* (Katz et al., 2006). Pictograms represent actions (i.e., putting drops in the eye) in a graphical way, with the aim that the underlying meaning is grasped independently of patients' literacy skills (Kolers, 1969). Though research has shown that pictograms improve patient understanding regarding the proper use of medicines and thereby also adherence, some studies show that pictogram-based interventions, as opposed to merely text-based ones, have not shown such successful results (Houts et al., 2006; Katz et al., 2006; Knapp et al., 2005; Montagne, 2013). The question is why?

Looking for a *specific* medical instruction (e.g., "do not take during pregnancy") in pictogram form in package inserts, or on drug boxes positioned on shelves, mimics a natural "visual search" task. In the laboratory this would be operationalized by participants having to search for a target object in a variable set (e.g., 6, 12, 18) of irrelevant distracting objects (which together define the so-called set size). Participants' response times (RT) are then plotted against the "set size". The

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[1] In addition to *general reading comprehension*, non-adherence can also be related to, for example, *medication literacy*. Medication literacy was defined by Pouliot et al. (2018) as "the degree to which individuals can obtain, understand, communicate, calculate, and process patient-specific information about their medication in order to make informed medication and health decisions to use their medications safely and effectively, …" (p. 801). Hence, medication literacy is a narrower and more specific term than *health literacy* in the context of medication use (see Pantuzza et al., 2020). Accordingly, although statistically significant, the meta-analysis by Zhang et al. (2014; see also Miller, 2016) found only a weak positive association between the conceptually broader term of health literacy and medication adherence.

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resulting RT x Set Size slopes (expressed in “ms/object”) are indicative of the additional costs that arise when an additional object must be compared with the target object template (Wolfe and Bennett, 1997). If the processing of objects becomes harder, slopes increase and search becomes less efficient. This is the case, for example, when searching for a T among L’s, where a slope of 20–50 ms per object results (see Wolfe and Horowitz, 2017). Now Maxfield et al. (2014) have shown that the better the features of the object to be searched for (e.g., abdomen of a pregnant woman) correspond to those of its category (e.g., pregnant woman), the more efficient search guidance becomes (Maxfield et al., 2014). Or, in other words, the more the T resembles the prototype of a letter T, the faster it can be found. Moreover, the authors found that in such a case an object could also be *verified* faster, which means that its meaning is captured faster. Hence, the target object is not only found faster, but also verified faster. Therefore, visual search tasks, by analyzing the search efficiency, provide valuable information about objects (here their quality) being processed.

The first goal of this study is, therefore, to investigate how newly designed pictograms compare to existing pictograms (see United States Pharmacopeia, USP) in terms of attentional guidance. To our knowledge pictograms have not yet been tested in a search context, but rather isolated (see e.g., Berthenet et al., 2016; Kanji et al., 2018; Merks et al., 2018; Ng et al., 2017). More recent studies show that the understanding of pictograms can also depend on influences like culture (Dowse and Ehlers, 2004; Kassam et al., 2004; Mansoor and Dowse, 2004) and context (Montagne, 2013; Tijus et al., 2007). Whereby context means any kind of additional information that is presented alongside the information to be conveyed (compare Montagne, 2013). In a pictogram displaying the application note “do not take during pregnancy” the additional representation of breasts and a face next to the abdomen with the fetus could, for example, represent such a context. However, we are not aware of any study investigating this role of context regarding pharmaceutical pictograms. Therefore, secondly, we will also investigate - using a classical visual search task - the differential effect of two types of newly designed pictograms, with or without context. Finally, visual search tasks have also shown that the memory size matters, that is, how many target objects one has to keep in mind while doing a search task (Wolfe, 2012); like finding a T and an X among L’s. Transferred to our context, this would mean searching the drug box for more or less specific pharmaceutical pictograms such as “do not take during pregnancy” and “dosage” at the same time. Why could this be important? If the search for more than one instruction becomes too complex, not only could the efficiency of the search decrease dramatically, but more often, target objects could be missed, which would be fatal. Since there is no study on the role of memory size in connection to pictograms, as a last goal we will also investigate how participants search through different memory sets.

2. Method

2.1. Participants

Thirty ZHAW (Zurich University of Applied Sciences; School of Applied Psychology) students took part in this laboratory experiment. Their age ranged from 22 to 44 years of age ($M = 29.6$, $SD = 6.1$), whereby 21 of them were female. All participants had normal or corrected-to-normal visual acuity and no color deficiency (tested after: Ishihara, 2012). Participants received course credit for their participation, and all provided written informed consent.

2.2. Apparatus and stimuli

The experiment was performed on a Mac Pro (Apple Inc., USA), programmed with the MatLab Software and presented with Psychtoolbox (Brainard, 1997; Pelli, 1997) on a 20-inch screen (Hewlett-Packard, USA). Participants were seated at a distance of 22 inch from the screen in a dark and quiet testing room.

Three types of pictograms with ten stimuli (or pictograms) each were used. Stimuli of the so-called “*original*” type were selected from USP pictograms (in the copyrighted version of 1997), with the exception of one that came from the FIP[2] system. The pictograms of the 2 other pictogram types, with and without context, were designed in collaboration with two designers from the ZHdK (Zurich University of the Arts). Fig. 1 shows one pictogram of each pictogram type (original, without context, with context; see Figure A1 in the appendix for the complete set of pictograms used). In designing these new pictograms, attention has been paid to simplicity, concreteness, the shape and color, etc. (see Mansoor and Dowse, 2004; Tijus et al., 2007). The newly designed pictograms are summarized under the name Pharmaceutical Pictogram System, or simply PPS.

2.3. Procedure and design

Participants were repeatedly presented with shelves containing either four, eight or twelve identical drug boxes (defining the so-called variable: set size; see Fig. 2), which could contain different numbers of pictograms per box (from one to three). The pictograms presented per individual shelf (e.g., muscle contusions, heart rhythm disturbances, etc.) were of the type original, no context or with context (variable: pictogram type). Per shelf, participants had to decide as quickly and accurately as possible whether there is a drug box on the shelf that complied with the medical instructions mentioned at the beginning of each trial (for example: “Do not take while pregnant”) or not by pressing one of two keys (yes/no) on a keyboard (variable: target presence). Half of the shelves contained a target object (target-present trials), the other half did not (target-absent trials), leaving us with the measures: reaction times (RT) and error rates. Thereby, the number of instructions the participants had to consider could vary from one to a maximum of three (variable: memory size). This leaves us with a 2 (target presence: present, absent) x 3 (pictogram type: original, no context or with context) x 3 (set size: 4, 8, 12) x 3 (memory size: 1, 2, 3) factorial design. Participants completed 10 practice trials followed by 1080 experimental trials.

3. Results

Reaction times (RTs) faster than 250 ms or slower than 10′000 ms were excluded from the data analysis (i.e., 0.74% in total); which is a standard procedure in analyzing results from visual search tasks. Furthermore, as there was no difference between the two context conditions (with and without) we collapsed the data of the PPS.[4]

The data for target-present and target-absent trials were analyzed separately. Fig. 3a shows the results for the 3-factorial ANOVA calculated on RTs for *target-present* data. All linear trends for the main effects were significant: set size: $F(1, 29) = 618.15, p < .001$, memory size: $F(1, 29) = 119.61, p < .001$, and (pictogram) type: $F(1, 29) = 151.53, p < .001$. This means that search became slower the larger the set size or memory size became, or if the original pictograms were used. Furthermore, we found a significant linear trend of Memory size x Set size interaction effect, $F(1, 29) = 46.61, p < .001$; meaning that the set size effect (seen in the slopes data: ms/object) became more pronounced the more information participants had to check for. Remember that the set

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[2] Note: The diarrhea pictogram of the FIP (International Pharmaceutical Federation) system was used because there is no equivalent in the USP system.

[3] For the sake of simplicity, only the abbreviation USP is used throughout the paper and not USP/FIP. Unless otherwise mentioned, the FIP pictogram is therefore always included.

[4] Since there was no significant difference (Bonferroni corrected) between with context and without context, $t(58) = 1.551, p = .379$ when equal variances are assumed, respectively $t(29) = -2.368, p = .074$ with inequal variances, we collapsed over these data.

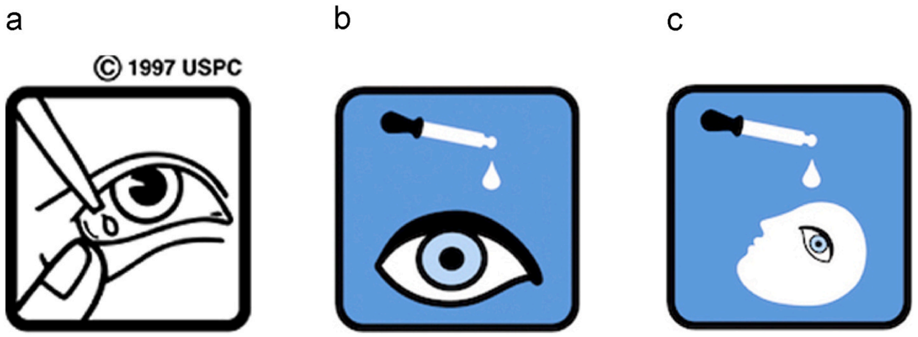

Fig. 1. Example pictograms used for “place drops in the eye”. Panel a: original (USP) pictogram respectively newly designed pictograms of the Pharmaceutical Pictogram System (PPS) without context in Panel b and with context in Panel c. Note, the copyright sign of the USP pictograms was omitted in the test.

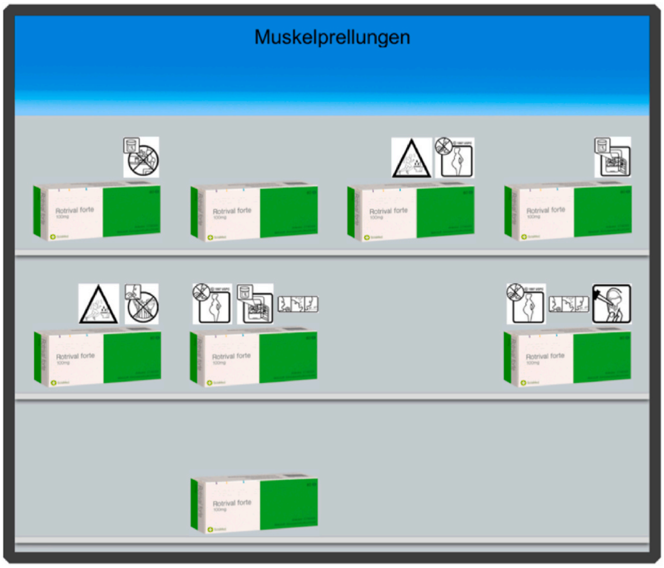

Fig. 2. Example of a shelf presentation with a set size of eight drug boxes showing original (USP[3]) pictograms (zero until maximum three pictograms per drug box).

size symbolizes how good search guidance is. As can be seen in Fig. 3b, mean RTs are a *linear* function of memory size (note that in Fig. 3a and b the same RTs are plotted; however, once as a function of set size and once as a function of memory size). These results are in contradiction to Wolfe (2012) who found a linear function of the *logarithm* of the memory size. Note, however, that in addition to the smaller set sizes 1, 2, and 4, Wolfe (2012) also used set sizes greatly beyond the limits of working memory (i.e., 8, 16). Hence, in our case, RTs are a linear function of the number of drug boxes on the shelf as well as the number of medical instructions to be held in memory. Finally, the Set size × Type interaction effect was also significant, $F(1, 29) = 23.31$, $p < .001$; meaning that the set size effect is more pronounced for the original, that is, the USP pictograms. Hence, the PPS pictograms require less processing and search guidance is more efficient. All other interactions were not significant (all p’s $> .447$)

Target-absent data showed an identical pattern, with slopes of about 2.1 times the target-present slopes. As in the target-present data the linear trend of the Memory size × Type interaction, as well as the three-fold interaction were not significant: both p’s > 0.394. Though, as can be seen in Fig. 3c, there is no difference between memory size 2 and 3 - Bonferroni corrected; $t(29) = 0.063$, $p = 1.000$.

However, regarding the safe use of pictograms, not only RTs but also errors, misses and false alarm rates matter. Overall, the task was quite easy; miss error ranged in between 3 and 18%, respectively false alarm rates between 1 and 3% (see for a comparison Table 1 of Wolfe, 2012). The *d’* statistics (a sensitivity index in signal detection) fell from 4.0 to 2.8. More specifically, the error rates for the target present data, that is, the *miss rates*, show a similar pattern as the RTs for target-present data: Significant linear trends for all main effects: set size: $F(1, 29) = 56.10$, $p < .001$, memory size: $F(1, 29) = 6.65$, $p < .05$, and pictogram type: $F(1, 29) = 10.49$, $p < .01$. Furthermore, we found significant linear trend interaction effects for all two way interactions (Set size x Memory size: $F(1, 29) = 8.46$, $p < .01$: Set size x Pictogram type: $F(1, 29) = 11.24$, $p < .01$, Memory size x Pictogram type: $F(1, 29) = 7.72$, $p < .01$). The 3-way interaction was not significant ($p = .657$). Regarding the target-absent data, the *false alarm rate*, we only found significant linear trends for the main effects memory size, $F(1, 29) = 4.71$, $p < .05$ and set size, $F(1, 29) = 15.71$, $p < .001$, and a significant linear trend for the Type x Memory size interaction, $F(1, 29) = 4.73$, $p < .05$. Everything else was not significant (all p’s > 0.378).

4. Discussion and conclusion

4.1. Discussion

Overall, the newly designed PPS pictograms (summarized under the term collapsed) guide search more efficiently to the target object than the original pictograms. This indicates that the PPS pictograms better *represent* the category to be searched for (e.g., “do not take during pregnancy”). That is, the eye in our PPS pictograms (see Fig. 1b and c), though more abstract, contains the typical features of an eye compared to the warped eye in the USP pictograms (Fig. 1A). Furthermore, considering past findings related to visual search tasks, the difference in *search efficiency* (ms/object) between the different pictogram types (collapsed and original) is *quite* huge; which is crucial in view of the fact that people’s attentional resources are limited (in time and space). Therefore, when designing future pharmaceutical pictograms, special care should be taken to depict the typicity of the target object.

In this regard, our results nicely agree with those of Maxfield et al. (2014), which are derived from “classical” visual search tasks, but also complement the more general results on *categorical guidance*. It has been shown, for example, that categorical guidance benefits not only from how well the target object is specified in the cue (search for an *abstract* object: e.g., footwear, or a *precise* object: e.g., boots; see Schmidt and Zelinsky, 2009, but see: Otsubo, 1988), but also at which categorical level the target object is specified (superordinate level: e.g., dessert, or basic level: e.g., ice cream, or subordinate level: e.g., chocolate ice cream, see Maxfield and Zelinsky, 2012). This means that cues (in our case this would have been the information to search for or the memory size) should be as specific as possible, or preferably its categorical name on the subordinate level.

To our knowledge, this is the first attempt to show that pharmaceutical pictograms can influence *search guidance*. So far research on pharmaceutical pictograms and attention has shown that isolated

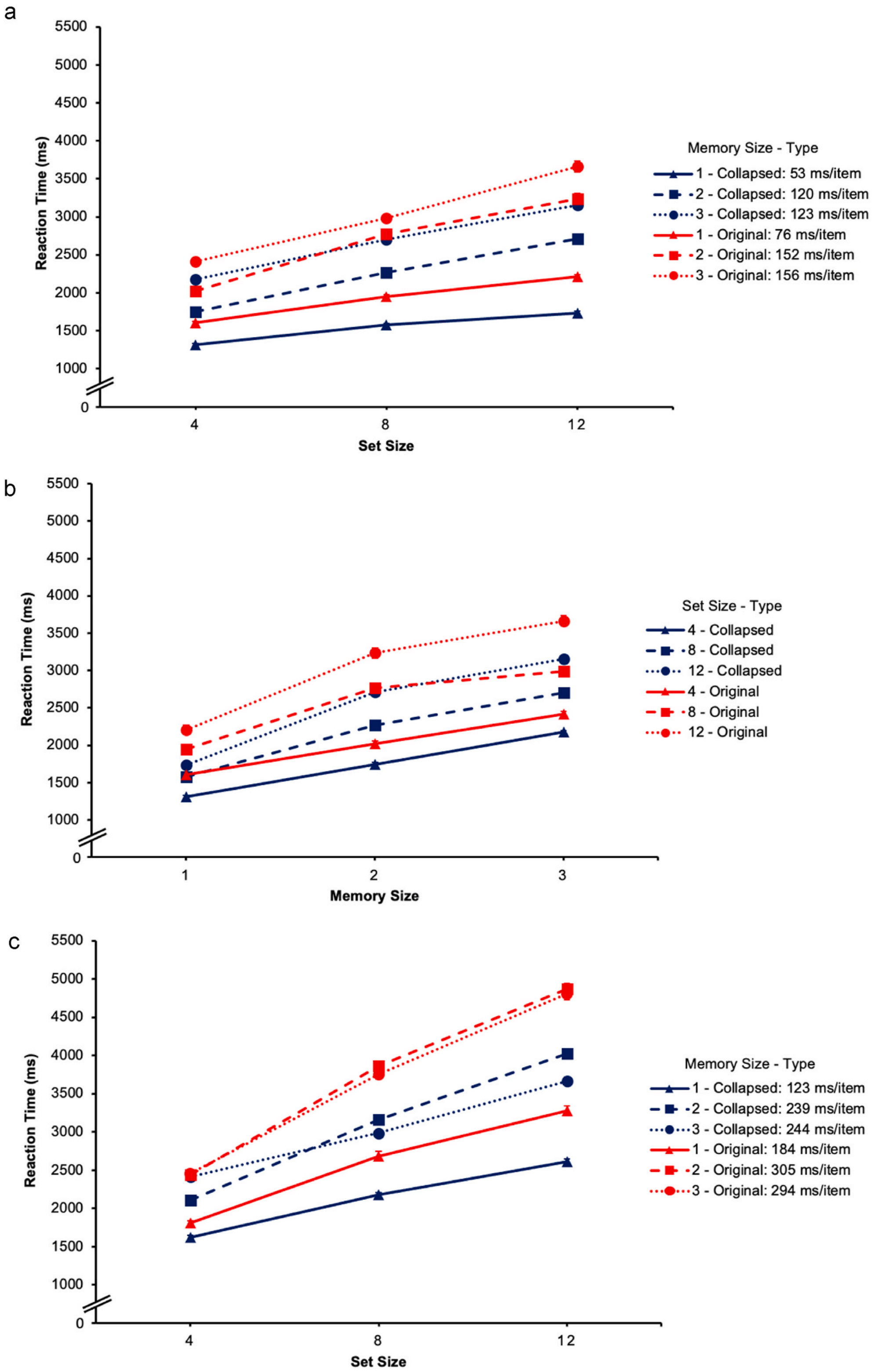

Fig. 3. Panel a: Shows reaction time (RT) on target-present trials as a function of set size for each of the 3 memory sizes; the key lists the slope of the RT × Set size function for each memory size. Panel b: Presents the same data, but in this case, the RTs are plotted as a function of memory size for each of the five set sizes. Panel c: Contains the data from target-absent trials.

pictograms (as opposed to mere text-based instructions) are not only beneficial in drawing attention to medical information, but also improve memory of and compliance with medical information (Houts et al., 2006).

However, our study surprisingly did not support Montagne's (2013) assertion that showing isolated body parts, or taking them out of context, leads to misinterpretation. We did not find a significant difference in search efficiency between the PPS pictograms with and without context. This could be an indication that the PPS pictograms without context already had the relevant information clearly visible or it

Table 1
Errors (in %).

Type	Set size								
	4			8			12		
	Memory size			Memory size			Memory size		
	1	2	3	1	2	3	1	2	3
Original									
Target present	7.2	7.3	5.0	15.2	12.9	7.7	18.1	16.3	11.9
Target absent	0.7	1.2	2.0	1.2	1.9	2.5	1.2	3.1	2.5
Collapsed									
Target present	4.7	3.3	5.1	7.9	6.7	8.3	11.0	8.5	8.5
Target absent	1.6	1.6	1.8	1.8	1.4	3.0	2.7	1.6	2.6

Note. Target present stands for “miss rates”, target absent for “false alarm rates”.

was simply because we tested the pictograms only on literate people. Perhaps we could have seen a difference if we had also tested people with low literacy skills. Especially since, for example, Dowse et al. (2010) found that people with low literacy skills preferred whole-body pictograms to pictograms that showed only the isolated parts, such as the hands. van Beusekom et al. (2015) did indeed find a difference depending on the people’s literacy skill, however, opposite to Dowse et al. (2010), they found that low-literate people preferred pictograms representing an isolated organ (e.g., the intestine) to pictograms representing that organ related to the body. A closer look at the data from van Beusekom et al. (2015) shows that difference is only found in regard to the intestines, lungs and kidneys, but not to the ear. Regarding the ear, no difference was found between low-literate and literate people: in both groups the isolated organ was the preferred one. Hence, depending on the organ, internal versus external, a different result was found. They speculated that even low-literate people are familiar with external organs. This leaves us with the question of whether we have tested known elements in all our pictograms. Further experiments can bring more clarification to this point.

Leaving aside the debate about whether or not effectively designed pictograms should add context, respective of its possible interaction with literacy skills, research showed that *older adults* in general also benefit from the use of pictograms (Ng et al., 2017). Following Wiegand and Wolfe (2020), who found no *age-related deficits in attention and memory*[5] in a task similar to ours (holding multiple target objects in memory), we wondered whether older adults would benefit from the PPS pictograms in a similar way to younger adults. Therefore, we conducted a pilot study, analogous to the main study, with 11 healthy older participants (66.0 years, 5 male, 6 female). Aside from a *general slowing* in older participants, similar to Wiegand and Wolfe (2020) we found no *age-related qualitative* search differences (tested with z-transformed data), with the following exceptions: First, the memory size effect was *less pronounced* (both in target-present and in target-absent data) in older participants than in younger ones. For the *target-present data* this means that the older participants not only showed relatively faster RTs than the younger participants, but especially in the large memory size “3” condition. However, for the target-absent data, the “shallower slope” has an opposite meaning; not only do the younger participants show relatively faster RTs than the older ones, but especially in the small memory size “1” condition. Second, in contrast to the younger participants, memory size and pictogram type interacted with each other in the older participants in the target-present data. Hence, older participants benefited more from the PPS pictograms in the small memory size than in the large memory size conditions. It follows that top-down guidance is not only preserved in older participants, but that our PPS pictograms also have positive effects (e.g., shallower “RT x Set size” slopes) in older participants.

Before we conclude, as far as error rates in the younger participants are concerned, overall, they were quite low. Although the miss rates were generally higher than the false alarm rates, the miss rates in the PPS pictograms were less sensitive to the set size than in the original or USP/FIP pictograms (a similar pattern could be observed in the older participants).

4.2. Conclusion

The newly designed PPS pictograms show an important advantage regarding search guidance and error rates and thus potential comprehensibility over the USP pictograms. Nevertheless, the PPS pictogram design could potentially be improved by a *rigorous*[6] “semiotic analysis”. Thereby the relevant features needed to recognize, for example, the pictogram “place drops in the eye” such as *eyes*, etc. are identified (see Korenevsky et al., 2013). Pictograms designed in that way can then be tested along parameters such as “translucency”, the perceived relationship between the image and its meaning (see, for example, Katz et al., 2006), and improved if necessary. The field of semiotics was influenced in particular by Saussure (see Thibault, 1996), who distinguished the components *signifier* (the form[7] of the sign) and *signified* (the represented concept) in relation to a sign. For example, the word “OPEN” (i.e., the signifier), which indicates that “the store is open” (i.e., the signified). Saussure’s approach was contrasted by Peirce (1991), another pioneer in this field. In contrast to Saussure’s dichotomous system, Peirce proposes a trichotomous system; while his “sign” component is more or less synonymous with Saussure’s signifier (e.g., it needs not to be material, Chandler, 2007), he divides Saussure’s signified into object and interpretant (the later in the sense of an idea that the sign evokes in people’s minds). Without going further into the differences between the two approaches, such as that for Peirce the “reality lies outside the internal structure of human and is not related to each other, while for Saussure, reality has a bond with our physical or human minds” (Yakin and Totu, 2014, p. 7), we want to focus on the three typologies or taxonomies of Peirce’s signs. Each taxonomy connects the signifier (here: sign or pictogram) with the signified (here: drops in the eye or eye drops) in different ways: iconic, indexical, and symbolic. Iconic signs are a direct visual representation of the object being depicted (e.g., the image of an eye to represent an eye); indexical signs, on the other hand, represent a lived experience associated with the object to be represented (e.g., a yawn that signals fatigue). Finally, symbolic signs represent an arbitrary learned association with the object being represented (e.g., a car representing driving). Now, the study by Lazard et al. (2017) shows that this taxonomy has relevance in that more abstract health effects (e.g., cancer) should be better represented by *symbolic* signs and less abstract health effects (e.g., reproductive organ

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[5] Note, that contrary results have been found in other studies (see, for example: Aziz et al., 2021; Fisk et al., 1994; Hahn and Buttaccio, 2018).

[6] In a less rigorous way, our designers did this by studying existing pictogram systems (e.g., FIP or Babica, 2009).

[7] Here not to be confused with shape.

damage) should be better represented by *iconic* signs, respectively. For example, although our PPS pictogram classifies eye drops as an iconic sign, respectively the fatigue pictogram as an indexical sign, the findings of Lazard et al. have not yet been considered systematically. For example, the question arises to what extent their "more/less abstract distinction" can be applied not only to health effects but also, as in our case, to general information, warning, etc.

Apart from the fact that the PPS pictogram design may leave room for improvement, we believe that the results found are not primarily due to the use of USP rather than FIP pictograms. Although USP pictograms are generally associated with *comprehension problems* (see Dowse, 2020), Kanji et al. (2018) and also Xu (2017) showed that the interpretation of USP pictograms was even better than that of FIP pictograms; this finding was also independent of whether participants had poor or good self-reported language skills. Accordingly, based on these findings, the expected slope rates for USP pictograms should not be higher than those for FIP pictograms.

To sum up, further testing should include not only the context of the intended use such as pharmacies (Montagne, 2013), or other/different study samples (e.g., people of different literacy skills and/or different cultural backgrounds), because our sample consisted of mainly younger students, but also what form of representation (e.g., symbolic) should be preferred to represent, for example, specific side-effects.

4.3. Practice implications

A pharmaceutical pictogram system that is universally understandable no matter the literacy, language, or health competence of the customer could be a tool to increase and ensure patient adherence. It could furthermore increase the safety of non-prescription medicine and be used in the battle against wrongly prescribed antibiotics and the associated increase in antibiotic immune bacteria. It could also lighten the load on pharmacies and doctors through an increase in our patient's health competence and self-efficacy. The goal is to achieve and establish a well-tested and ISO-standard (9186) certified set of medical pictograms. The pictograms could be adapted to be used as stickers by the commercial distributors or be directly printed on the boxes by the manufacturer.

Although the visual search paradigm is now used in applied domains (e.g., mammography, see for a review; Wolfe and Horowitz, 2017), it has not yet been used to assess the quality of pharmaceutical pictograms. Hence, the findings of the study in terms of pictogram design and visual processing could also be transferred to other fields of research, for example, to optimize safety pictograms on traffic signs. There would also be possibilities to transfer the knowledge into fields that do not work with a lot of visual representation of consequences at the moment. The food industry, for example, could profit from pictograms that show information for customers suffering from allergies, diabetes, or high blood pressure.

In the end, pictograms to increase public health would most likely need to be financed by the government, but considering the additional cost that non-adherence creates, the price would be way less than the savings in money and health.

Author contribution

The authors ER, LLV, SJK were equally involved in all steps of the manuscript. NM was involved in the conceptualization and testing of the participants, JF made a significant contribution to the writing, CV did the programming and supported RA in the formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Pictograms were designed by U. Binder and T. Gfeller.

Appendix

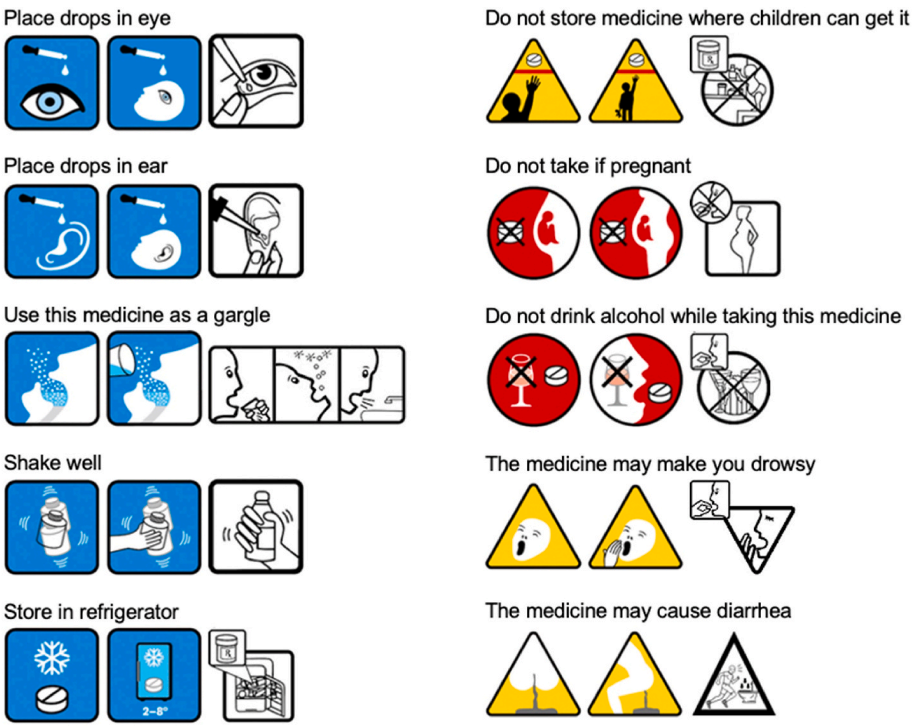

Fig. 1A. Complete Set of Pictograms. *Note*. The first pictogram of each triplet is the PPS pictogram *without context*, the second is the PPS pictogram *with context*, and the third is the *USP / FIP* pictogram..

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