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Authors
Malhotra, Rahul
Tan, Yi Wen
Suppiah, Sumithra Devi
et al.

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Pharmaceutical pictograms: User-centred redesign, selection and validation

Rahul Malhotra [a,b,*], Yi Wen Tan [a], Sumithra Devi Suppiah [a], Sarah Siew Cheng Tay [c], Ngiap Chuan Tan [c], Jianying Liu [c], Gerald Choon-Huat Koh [d], Alexandre Chan [e], Régis Vaillancourt [f], PROMISE Study Group [1]

[a] Centre for Ageing Research & Education, Duke-NUS Medical School, Singapore
[b] Health Services and Systems Research, Duke-NUS Medical School, Singapore
[c] SingHealth Polyclinics, Singapore
[d] Saw Swee Hock School of Public Health, National University of Singapore, Singapore
[e] Department of Clinical Pharmacy Practice, University of California, Irvine, USA
[f] Department of Pharmacy, Children's Hospital of Eastern Ontario, Canada

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ABSTRACT

Objective: In an earlier study, several tested International Pharmaceutical Federation (FIP) pictograms did not achieve validity among older adults in Singapore. In this study, for 27 unvalidated FIP pictograms, we (1) developed variants of each pictogram, (2) elicited the most-preferred variant, and (3) assessed the validity of the most-preferred variant among older Singaporeans.
Methods: In phase 1, up to three variants of the 27 pictograms were developed, based on older adults' feedback from a previous study. In phase 2, the most-preferred variant of 26 pictograms, which had two or three variants, was selected by 100 older participants. In phase 3, the 27 most-preferred variants (including the pictogram with only one variant) were assessed for validity – transparency and translucency – among 278 older participants (10 pictograms per participant). To evaluate transparency, participants were first asked: "*If you see this picture on a medicine label, what do you think it means?*" for each assigned pictogram. If they responded, they were asked, *"How do you know?"*, and if not, they were told, "*Tell me everything you see in this picture*". Then, participants were shown their assigned pictograms again, one by one, and the pictogram's intended meaning was revealed to evaluate translucency. Pictograms were classified as valid (≥66% participants interpreted its intended meaning correctly [transparency criterion] and ≥85% participants rated its representativeness as ≥ 5 [translucency criterion]), partially valid (only transparency criterion fulfilled) or not valid.
Results: In phase 1, 77 variants of the 27 pictograms were developed. In phase 2, a majority of the most-preferred variants were selected by >50% participants. In phase 3, 10 (37.0%) of the 27 pictograms tested were considered valid, and five (18.5%) were partially valid. A higher proportion of pictograms portraying dose and route of administration and precautions were valid or partially valid, versus those depicting indications or side effects.
Conclusion: Contextual redesigning and selection of pharmaceutical pictograms, which initially failed to achieve validity in a population, contributed to their validation.
Innovation: The redesigned validated pictograms from this study can be incorporated into relevant patient information materials in clinical practice.

1. Introduction

Pharmaceutical pictograms, defined as standardised graphic images that help communicate medication instructions, precautions, and/or warnings to patients and consumers, have been shown to capture attention, increase medication understanding, [1,2] and enhance medication adherence [3] and recall [4] among patients. Yet, not all pictograms are well-understood or well-received by their intended users. In particular, older (versus younger) adults and less (versus more) literate individuals face difficulties in comprehending pictograms [5-9]. To maximise their

* Corresponding author at: Health Services and Systems Research, Centre for Ageing Research & Education, SingHealth Duke-NUS Global Health Institute, Duke-NUS Medical School, 8 College Road, Level 4, 169857, Singapore.
E-mail address: rahul.malhotra@duke-nus.edu.sg (R. Malhotra).

[1] PROMISE Study Group (listed alphabetically, after the Principal Investigator): Rahul Malhotra; Alexandre Chan; Csilla Weninger; Esther Siew Joo Bek; Gerald Choon-Huat Koh; Imel Tang; John Carson Allen; Juliana Bte Johari; Kuan Cheong Chan; Lita Sui Tjien Chew; Ngiap Chuan Tan; Régis Vaillancourt; Sarah Siew Cheng Tay; Sumithra Devi Suppiah; Ting Yee Lee; Valerie Shu Ying Tan; Wee Ping Ang; Wern-Ee Tang; Yi Wen Tan.

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effectiveness, pictograms may have to be culturally modified for targeted demographic profiles [4,8,10-14]. A Canadian study found that pictogram modifications, such as variation of facial features and inclusion of traditional food, resulted in positive feedback from First Nation community members [13]. Likewise, studies conducted among Thai and African populations showed that pictograms that were either developed locally or culturally-appropriate achieved good comprehensibility and user acceptability [3,11,15]. However, subsequent validation of redesigned pictograms is also necessary prior to their use in practice [16].

A pictogram modification process that is rigorous, iterative and user-centred increases the chances of designing well-comprehended and accepted pictograms [17,18]. Involving intended users in the pictogram development process can help designers better address user mental models, needs and preferences [19]. For instance, users could be given the opportunity to comment on a pictogram's aesthetic appeal and its relevance to their daily health-related practices [18]. Broadly, there are three levels of user involvement – informative, consultative and participatory [17]. The least active level is informative, in which users serve as subjects for observation, such as during comprehensibility testing of pictograms. The second level is consultative, in which users provide feedback on pictogram design, such as during translucency testing where they comment on the pictogram's applicability and clarity in the context of its intended meaning. The most active level is participatory, where users wield a degree of creative freedom or decision power in pictogram selection, such as choosing their most preferred pictogram among a few options. Such preference testing has been done in previous pictogram evaluation studies, particularly when multiple pictogram designs or variants (a variant is defined as an alternative graphical symbol design for a given referent [i.e., a concept that a graphical symbol is intended to represent] [20]) are available for a particular medication instruction [12,13]. Other similar studies have asked participants to pick their preferred pictogram among variants from different sources, such as the *Fédération Internationale Pharmaceutique* (FIP; International Pharmaceutical Federation) and the United States Pharmacopeia (USP), or sourced locally, or from the Internet [15,21].

In Singapore, the setting of this study, almost two-thirds of adults aged ≥65 years cannot read in English [22]. Thus, in a previous study, we assessed the validity of 52 FIP pictograms among older adults with limited English proficiency, as they would potentially benefit the most from pictograms [9]. Validity was assessed by evaluating the pictograms' transparency (i.e., pictogram is correctly comprehended by the participant without telling him/her about its intended meaning) and translucency (i.e., the extent to which the pictogram represents its intended meaning, as rated by the participant once he/she is told its intended meaning) – further details are available elsewhere [9]. Pictograms were classified as valid (≥66% participants interpreted the pictogram's intended meaning correctly [transparency criterion] and ≥85% participants rated its representativeness as ≥5 [translucency criterion]), partially valid (only transparency criterion was fulfilled) or not valid [9].

We found that majority of the pictograms (32 out of 52; 61.5%) in our previous study did not meet the stipulated validation criteria [9] Furthermore, in the previous study, we obtained open-ended feedback from participants to aid modification of the tested pictograms, if needed [9]. In the current study, we focused on redesigning and testing a selection of the 32 pictograms that did not meet the validation criteria in our previous study [9], taking an iterative and user-centred pictogram development approach that incorporated all three levels of user involvement detailed above. Among the 32 pictograms, five pictograms deemed to be less relevant for clinical practice for older adults were excluded, resulting in 27 unvalidated pictograms for redesigning and testing. Thus, in continuation from our previous study [9], the current study conducted among older adults in Singapore, aimed to 1) develop variants, based on participant feedback, of each of the 27 unvalidated FIP pictograms, 2) conduct participatory preference testing to select the most-preferred variant of each pictogram, and 3) assess the validity of the 27 most-preferred variants (i.e., redesigned pictograms) by evaluating their comprehensibility and translucency.

2. Methods

This study is part of a health services research project titled "Prescription Medication Label Improvement for Singaporean Elderly" (PROMISE), aimed at provide the evidence-base for developing and implementing context- and culturally-appropriate prescription medication labels (PMLs) [9].

The current study comprised three phases – Phase 1: Development of variants of the 27 pictograms; Phase 2: Preference testing of the variants; and Phase 3: Validation of the 27 most-preferred variants (Fig. 1).

2.1. Phase 1

For each of the 27 unvalidated FIP pictograms, we developed one to three variants, using feedback gathered from older adults in our previous study on how each pictogram could be made more comprehensible and appropriate for older adults in Singapore [9]. This enabled older adults with limited English proficiency, arguably the ones who may benefit the most from pictograms, to play a consultative role in the redesign process [17]. Three study team members (R.M., S.D.S., Y.W.T.) conceptualised the variants and compiled the concepts into a design brief, along with internet-derived images, where appropriate, for clearer communication of the design idea. Based on the design brief, the study team worked collaboratively with a graphic designer to design and refine the graphic elements of the variants. After several iterations, 77 variants were developed. Most pictograms had three variants, while "difficulty in sleeping" and "take 1 hour before food" had two variants, and "half tablet" had one variant. The accompanying text of the FIP pictogram, "take on empty stomach", was also modified to "take 1 hour before food" (Table 1), as the latter instruction is more commonly used in Singapore. All accompanying text was available in English, Mandarin Chinese, Malay and Tamil [9].

2.2. Phase 2

For each of the 26 pictograms with two or three variants (the "half tablet" pictogram had one variant, thus was excluded from this phase), a forced-choice preference test was conducted to evaluate which variant best represented the pictogram's intended meaning, from a user perspective. This enabled participants to take on a participatory role in selecting their preferred variant [17].

Recruitment and questionnaire administration were done remotely (due to COVID-19). A convenience sampling approach was used. A recruitment advertisement was shared on social media platforms, requesting interested older adults (60 years and above) to contact the study team via phone call or email, who were then screened for eligibility over phone calls. The eligibility criteria (all to be met, self-reported) were: (1) age ≥ 60 years; (2) Singapore citizen/permanent resident (PR); (3) had taken/used medications in the past 3 months; (4) no cognitive impairment; (5) able to read the fine print in a newspaper; and (6) able to speak at least one official language of Singapore (English, Mandarin Chinese, Malay, or Tamil).

Data collection was done using Zoom®, a video conferencing platform, in the participant's preferred language. The "share screen" functionality on Zoom® was used to share survey materials with participants when administrating the demographic questionnaire, followed by the preference test. All participants started with a practice slide to familiarise them with the preference testing procedure. Next, they were shown 26 sets of variants (one Microsoft PowerPoint® slide depicted one set), one at a time. Each set comprised the two or three variants of one of the 26 pictograms along with its intended meaning. For each set, participants were asked "Which one of the pictures best represents (intended meaning of the pictogram)?", followed by an open-ended question, "Why did you choose this picture?". The order in which the 26 sets were shown, and within each set, the order of the variants, was randomised (the random allocation sequence generated a priori using a user-written SAS program). For each set, the most preferred variant of the pictogram was collated (Table 1).

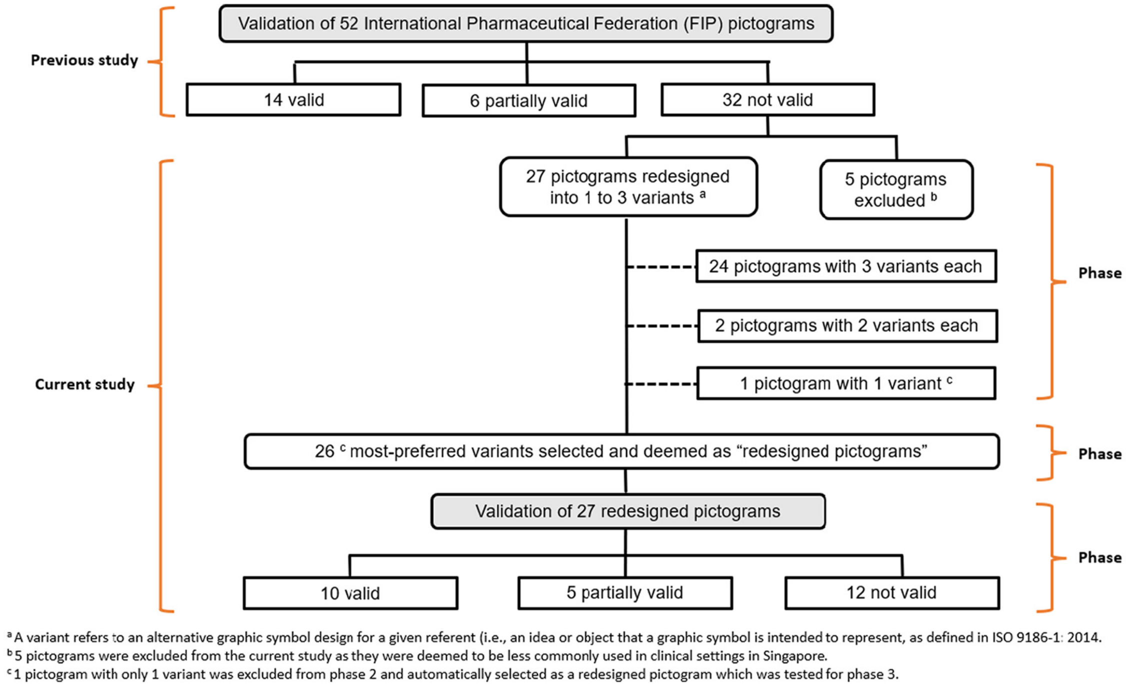


Fig. 1. Flow chart for the three phases of the study.

2.3. Phase 3

The 26 most preferred variants from phase 2, and 1 redesigned pictogram ("half tablet") excluded from the preference test, were evaluated in phase 3. These pictograms were classified into three categories: dose and route of administration ($n = 3$), precautions ($n = 9$), and indications or side effects ($n = 15$). The pictogram validation procedure, utilising transparency and translucency testing, was applied in this phase [9].

Two recruitment modes – remote and in-person – both adopting a convenience sampling approach, were used. The remote recruitment process was similar to that adopted in phase 2. For in-person recruitment, a research staff approached older adults at a public primary care clinic (polyclinic) to explain the study and screen interested participants for eligibility. The eligibility criteria (all to be met, self-reported) applicable to both recruitment modes were: (1) age ≥60 years; (2) Singapore citizen/PR; (3) received prescription medications in the past 3 months; (4) no cognitive impairment; (5) able to read fine print in a newspaper; and (6) can speak at least one official language. In addition, the Abbreviated Mental Test (AMT; for cognitive status) [23] was administered in both recruitment modes. However, the inclusion criteria differed for the two recruitment modes due to feasibility of administration: ≥ 3 correct responses on 5 selected questions from the AMT for remote recruitment and ≥5 correct responses on the AMT for in-person recruitment.

The full AMT included the following questions: (1) What is the present year?; (2) What time is it now?; (3) What is your year of birth?; (4) What is your age?; (5) Where are we now?; (6) What is your home address?; (7) Who is Singapore's present Prime Minister?; (8) *[Show showcards of a 'doctor' and 'nurse']* What are their occupations?; (9) Count backwards from 20 to 1; (10) Please recall the memory phrase (Answer: The phrase had been told to the participant at the start of the AMT). For remote recruitment, only questions 1, 2, 7, 9 and 10 were feasible to be administered over the phone (as it was not possible to verify the correctness of participants' response for the other questions).

For remote recruitment, 158 potential participants were screened for eligibility, of which 140 (88.6%) met all eligibility criteria and were recruited. However, data collection for 2 participants was incomplete, thus data for 138 participants were included in the final analysis. For in-person recruitment, 941 polyclinic patients were approached. A total of 402 (42.7%) individuals agreed for eligibility assessment and 148 met all eligibility criteria, of which 140 (94.6%) were recruited.

All participants were first administered a demographic questionnaire, followed by the pictogram validation procedure. For participants interviewed remotely, data collection was via Zoom®, utilising the "share screen" functionality to share survey materials. For participants interviewed in-person, the pictograms were presented using Microsoft PowerPoint® slides on a laptop. This ensured that pictogram testing was conducted similarly, despite different data collection approaches.

The relevant International Organisation for Standardization (ISO) standard recommends each pictogram to be assessed by at least 50 participants [20] – in our study, the number of participants per pictogram ranged from 99 to 105. Each participant was assigned 10 pictograms (to minimise respondent burden), using a random allocation sequence generated a priori using a user-written SAS program (to minimise learning effect). The 10 assigned pictograms were shown one at a time. Briefly, to evaluate transparency, participants were asked: *"If you see this picture on a medicine label, what do you think it means?"* for each pictogram. If the participants responded, they were asked, *"How do you know?"*. If not, they were told, *"Tell me everything you see in this picture"*. Once the 10 pictograms had been evaluated for transparency, participants were shown their assigned pictograms again, one by one, and this time, the pictogram's intended meaning was revealed to evaluate translucency. Participants were asked, *"How well does this picture represent the intended meaning? Please rate on a scale of 1 to 7, where 1 is 'does not represent' and 7 is 'completely represents'."* [9]. Participants' responses during transparency evaluation were audio recorded, transcribed, and translated if necessary.

PROMISE was approved by the National University of Singapore (NUS-IRB Reference number: S-17-341) and SingHealth Centralised Institutional Review Board (CIRB Reference number: 2017/3023). Waiver of documented informed consent (i.e., only verbal consent was sought) was approved for interviews conducted remotely. Participants interviewed in-person provided written informed consent.

2.3.1. Grading of pictogram comprehension

Any three of four study team members (R.M., S.D.S., Y.W.T., J.Y.L.) graded the participants' responses. First, each team member independently read the response provided during transparency testing for each assigned

Table 1

27 pictograms assessed in the study: Intended meaning, original International Pharmaceutical Federation (FIP) version and feedback on it from older adults, modified variants, and results of preference testing.

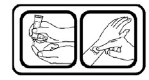
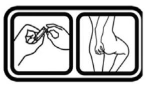
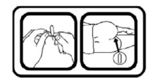
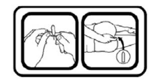
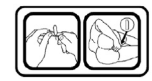
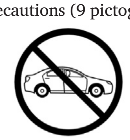
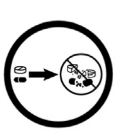
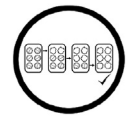
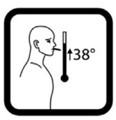
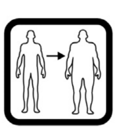
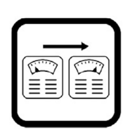
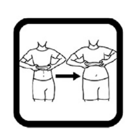
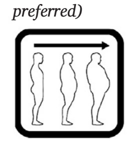
Intended meaning	Original FIP version	Feedback on the original FIP version from older adults	Variant 1 [a]	Variant 2 [a]	Variant 3 [a]
Pictogram category: Dose and route of administration (3 pictograms)					
Apply to affected area		• Looks like a piece of (medicated) cloth being rubbed on the hand. • Looks like applying a plaster. • Looks like a bandage. • Looks like the arm is being massaged.			
Preference testing result			*38%*	*47% (Most-preferred)*	*15%*
Insert 1 suppository		• First picture looks like a nail clipper, unknown object or medicinal cream. • Suppository can be drawn longer. • Cannot see the suppository being inserted into the buttocks as the hand is blocking the suppository. Looks more like scratching the buttocks. • Looks like back or leg pain because his leg is propped up.			
Preference testing result			*7%*	*52% (Most-preferred)*	*41%*
Half a tablet		• The shape of the tablet looks too square. • Prefer a 2-D rounder half tablet. • Prefer to see a hand holding the tablet. • Face to be improved.		–	–
Preference testing result			Not applicable		
Pictogram category: Precautions (9 pictograms)					
Do not drive		• Having one line across the picture does not convey "do not drive". • Car looks stationary. Looks like parking, not driving. • Draw a person in the car to show driving. • Difficult to draw a link between medicines and the image of a car.			
Preference testing result			10%	20%	70% *(Most-preferred)*
Take with food		• Cannot relate (the idea of) "taking food" with medications.			
Preference testing result			18%	77% *(Most-preferred)*	5%
Keep out of reach of children		• The cupboard looks too low. • The medicine box looks like a car. • The mother looks like she is "waving". • The locked cabinet looks like a "kitchen". • Medicines in the locked cabinet are unclear.			
Preference testing result			57% *(Most-preferred)*	14%	29%
Shake		• Looks like preparing to draw blood. • The bottle looks like a squeezable "stress ball". • The hand is unclear. • Looks like exercising the muscle.			
Preference testing result			23%	19%	58% *(Most-preferred)*
Do not eat grapefruit or drink grapefruit juice[b]		• The fruit is unclear as there is no colour. The drawing needs to be improved; to make it more obvious that it is grapefruit. • Translate "grapefruit" into Tamil, Chinese and Malay. • The juice looks like soft drink. • Having 3 items is confusing (A full grapefruit, a cut grapefruit and the juice).			
Preference testing result			56% *(Most-preferred)*	14%	30%
Take on empty stomach/ Take 1 hour before food [b, c]		• The drawing does not look like a body. Unable to identify the (shape of the) stomach. • No belly button, does not look like a stomach. • Stomach looks like a "heart" or "mango". • Stomach is not round enough.			–
Preference testing result			32%	68% *(Most-preferred)*	
Do not crush		• Looks like a hamburger. • Looks like trash. • Tablets looks too squarish. Needs to be rounder.			
Preference testing result			8%	41%	51% *(Most-*

Table 1 (*continued*)

Intended meaning	Original FIP version	Feedback on the original FIP version from older adults	Variant 1 [a]	Variant 2 [a]	Variant 3 [a]
					preferred)
Seek medical advice		• Telephone is unclear. Need to add a telephone cord. • Seems like the doctor is attending to a call. • Doctor looks like a monk. • The telephone looks like a stethoscope.			
Preference testing result			37%	39% *(Most-preferred)*	24%
Take until finished		• Tablets are not clear. Cannot be seen clearly. • Looks like sweet e.g. tic-tac®			
Preference testing result			26%	34%	40% *(Most-preferred)*
Pictogram category: Indications or side effects (15 pictograms)					
Fever		• The thermometer in the mouth looks like a cigarette or karaoke microphone. • Do not colour the thermometer black. It is also too small. A hand should be holding the thermometer. The thermometer should have lines to indicate temperature. • Show the person feeling hot. Or hold a hand to the forehead to feel for fever.			
Preference testing result			11%	36%	53% *(Most-preferred)*
Muscular pain		• The drawing does not look like a person's arm. Cannot tell which part of the body this is. • Draw the whole body or hands or face so we know the body part. Or draw a shirt's sleeve. • Draw his face expression to show pain • Electricity symbol means electrocution. Instead, use a hand to press on it to mean "pain". • The shaded area should be on the outer arm. If the shaded area is on the inner arm, it could be misinterpreted as chest pain.			
Preference testing result			12%	37%	51% *(Most-preferred)*
Drowsiness		• Do not need to cover the mouth, as it may be misinterpreted as cough or toothache. • Make it larger or more obvious that the eyes are closed. • Hands should be placed at the side of her head. • Do not colour the mouth black. • Eye wrinkles were misinterpreted as tears.			
Preference testing result			32%	5%	63% *(Most-preferred)*
Sensitive to sunlight		• The hand does not look like a hand. • The sun (circle) should be above him, not beside him. • Draw the sun ray (lines) shorter and draw them shining directly on the black patches. • There should be more black patches on his skin. • Draw an umbrella or a cross (to mean stay out of the sun). • Draw another hand scratching the skin.			
Preference testing result			13%	12%	75% *(Most-preferred)*
Constipation		• More sweat droplets. • Some elderly feel that the 'sweat' represents constipation well while a few do not understand it. • Hands should be put on the abdomen. He should be bending forward. • The facial expression is not obvious enough. He needs to look more worried or in agony or frowning. • Cannot tell whether it is diarrhea or constipation.			
Preference testing result			34%	25%	41% *(Most-preferred)*
Weight gain		• Add a weighing scale. • Draw an actual person instead of just the silhouette. • Draw another person who is middle size between them. • Write 50 kg to 60 kg or "light" and "heavy". • Add a plus sign on the arrow.			
Preference testing result			14%	17%	69% *(Most-preferred)*
Tremors or Shaky hands		• Looks like washing hands. • Fingers have to be curved or bent downwards. They should not show '5' or be spread so open.			

(continued on next page)

Table 1 (*continued*)

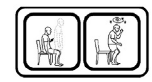
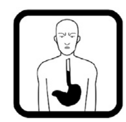
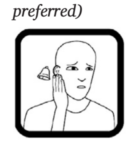
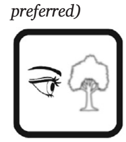
Intended meaning	Original FIP version	Feedback on the original FIP version from older adults	Variant 1 [a]	Variant 2 [a]	Variant 3 [a]
		• The lines do not clearly express the meaning of shaking or moving. (But some elderly feel that the lines do show shaking or moving) • Draw 3 hand shadows to show movement. Also draw the side view of the 3 hands.			
Preference testing result			52% *(Most-preferred)*	33%	15%
Diarrhea		• Toilet bowl is not clear as it is covered. • Lines near mouth or forehead can be misinterpreted as cough or vomiting. • The man does not look sick.			
Preference testing result			12%	26%	62% *(Most-preferred)*
Giddy when getting up		• Looks like back pain due to the arrow. • The stars on top are too small. Draw them bigger or clearer. • The position of the hands is unclear. The hands should be nearer to the head or touching the head. • Touch the wall or chair for support • Show the person sitting or getting up from the chair. • Person should wear clothes. He looks like he is exercising without clothes.			
Preference testing result			44% *(Most-preferred)*	26%	30%
Gastric or Reflux		• Commonly misinterpreted as heart and chest pain. • Draw the reflux up till the oesophagus. Draw an arrow up. • Draw a side view, with the gastric juices from the stomach coming out through the throat. • There should not be a fire. Just the hand and stomach are enough. • The hand should not be pounding the chest, the hand should be pressed flat on the chest. • The stomach does not look like a stomach. • Draw the stomach upside down or draw an arrow to reflect reflux. • Reflux should cause burping. Put the black portion (gastric juice) on top, white at the bottom to show air going up. • Draw someone lying down and salivating, with gastric juice leaking from the mouth.			
Preference testing result			6%	2%	92% *(Most-preferred)*
Ringing in ears		• The bells represents alarm or noise to inform others of something. • The person is smiling or has no expression. • Ringing in ears means the noise is from inside the ear, not outside. • Draw soundwaves or wavy lines coming out of the ears. • Draw a bug, bee or a symbol to represent the sounds coming out of the ear. • Draw the ears clearly. • Draw the person pointing to his ears.			
Preference testing result			70% *(Most-preferred)*	25%	5%
Difficulty in sleeping		• He looks asleep. Do not draw him lying down and covered with a blanket. • Eyes look closed. Should draw them opened bigger but still proportional to the face. • Draw the moon and stars higher or further away. Or remove the moon. Otherwise it looks like he is dreaming, breathing or admiring the moon. • Draw 2 pictures to show that he is turning and tossing his head, trying to sleep. Or draw one of him getting up and one sitting up. • Draw some clouds above his head to show he is thinking while having insomnia. • Draw the hands in a fist near his head, a crumpled blanket near the feet, big eyes looking at the ceiling.			–
Preference testing result			36%	64% *(Most-preferred)*	
Blurred vision		• The eye does not look like an eye. Need to redraw. • Draw more eyelashes. Draw the eyebags lower and unattached to the eyelid. Draw a front view of the eye. • Draw the entire face. • Draw the eye to be more blurry in front. • Draw the "A" more blurry. • Some elderly may not understand "AAA". Replace with a blurred image, or some clouds, mist, fog, or grey colour instead of black. Draw 1 clear "A" and 2 unclear "A"s. • Show the eye getting smaller.			
Preference testing result			29%	17%	54% *(Most-preferred)*

Table 1 (*continued*)

Intended meaning	Original FIP version	Feedback on the original FIP version from older adults	Variant 1 [a]	Variant 2 [a]	Variant 3 [a]
Confusion		• The exclamation mark is confusing. • The question marks near the ear are confusing and may be misinterpreted as having ear problems. • The expression looks like thinking or pondering. • Looks like he had a stroke, because of the slanted mouth.			
Preference testing result			21%	6%	73% *(Most-preferred)*
Difficulty in breathing		• Looks like spitting phlegm or cough. • His hands should be placed at his abdomen or chest. • His body should be straight to facilitate breathing. He is bent too far. • His head should be tilted back and raised slightly. • Draw arrows or air to show both inhalation and exhalation at the nose. • The exhaled breath should be drawn with a cloud shape or circle, no need for the sharp edge. • Show the shoulders heaving.			
Preference testing result			63% *(Most-preferred)*	27%	10%

[a] The variants belong to the PROMISE Study Team and collaborators. Copyright © 2022. PROMISE Study Team. National University of Singapore, Duke-NUS Medical School, in collaboration with Ministry of Health Singapore, National Healthcare Group Polyclinics, National Healthcare Group Pharmacy, SingHealth Polyclinics, and National Institute of Education, National Technological University. All Rights Reserved.

[b] For pictogram variants containing English text, “grapefruit” and “wait 1 hour”, the English text was translated into Mandarin Chinese, Malay and Tamil. Participants who preferred to read in a language other than English were shown the variant that had “grapefruit” and “wait 1 hour” translated in their preferred language.

[c] The accompanying text for the original FIP pictogram “take on empty stomach” was modified to “take 1 hour before food” for the redesigned variants.

pictogram, and performed a preliminary grading – correct, partially correct, incorrect, opposite or no response – in context of its intended meaning. Inter-rater reliability for preliminary grading was almost perfect, with percent agreement = 0.93 [95% Confidence Interval: 0.93–0.94], Fleiss' Kappa = 0.85 [0.83–0.87] and Krippendorff's Alpha = 0.85 [0.83–0.87] (Supplementary Table 1). Subsequently, these preliminary grades were discussed to achieve consensus. Responses that were initially graded as partially correct were re-graded as correct, incorrect, or opposite. Our previous study provides further details on the grading process [9].

2.3.2. Data analysis

For phase 2, the frequency of selection of variants within each set was tabulated for each of the 26 sets of pictogram variants. Descriptive statistics were used to summarise the socio-demographic data.

For phase 3, for each pictogram, the proportion of participants with a correct response and the proportion who rated its representativeness as ≥5 was tabulated. Descriptive statistics were used to summarise socio-demographic data. Linear regression was used to assess participant characteristics associated with the proportion of assigned pictograms correctly comprehended by the participant (range: 0% to 100%; continuous variable). The soundness of random allocation of the pictograms was also examined (Supplementary Additional Methodology Details and Supplementary Table 2). All analyses were performed with Stata15.

3. Results

3.1. Phase 1

The variant development phase lasted between September 2019 to May 2020. A total of 77 variants were developed (Table 1; it also presents the original FIP version).

3.2. Phase 2

A total of 112 potential participants were screened for eligibility between June and July 2020, of whom 100 were recruited (Supplementary Fig. 1). Their mean age was 68.4 (± 6.1) years, majority were females (67.0%) and of Chinese ethnicity (88.0%) (Table 2).

Among the 26 sets of variants tested, the most preferred variant in each set mostly had more than 50% of participants selecting it. Five exceptions were “apply to affected area” (47%), “giddy when getting up” (44%), “constipation” (41%), “seek medical advice” (39%) and “take until finished” (40%) (Table 1). A summary of participants' reasons for selecting each variant is presented in Supplementary Table 3.

3.3. Phase 3

A total of 278 participants were recruited from September 2020 to February 2021. Further recruitment details are provided in Supplementary Fig. 2. The participants' mean age was 68.8 (± 5.5) years. Just over half were female (51.1%) and of Chinese ethnicity (93.2%) (Table 2).

Of the 27 pictograms tested, 10 (37.0%) pictograms were considered valid. Another five (18.5%) pictograms were partially valid, nonetheless, they had relatively high translucency scores (73.5% to 80.8%). In total, 55.6% of the redesigned pictograms were valid or partially valid. A higher proportion of pictograms portraying dose and route of administration (66.6%; 2 of 3), and precautions (77.8%; 7 of 9) were valid or partially valid, versus those depicting indications or side effects (40.0%; 6 of 15) (Table 3).

On average, participants correctly comprehended 64.7 ± 18.8% of their assigned pictograms on transparency testing. An increase in participants' age was associated with understanding of fewer of their assigned pictograms, while participants with tertiary and university and above education (versus no formal or primary education) comprehended a higher proportion of their assigned pictograms (Table 4).

4. Discussion and conclusion

4.1. Discussion

In our study, first, 77 variants of 27 pictograms were developed based on older adult feedback. Next, older adults' preferences informed the variants to be assessed for validation, which was then conducted for 27 pictograms among older adults. Just over half (55.6%) of the 27 pictograms were valid or partially valid.

We now discuss methodological issues related to preference testing and the findings from the validation study in the context of prior research.

4.1.1. Preference testing of variants

The variant preference testing methodology adopted in this study aligns with the approach used previously [12,13,15,21]. This method is also akin to the judgement test described by (an older version of) the ISO standard

Table 2
Distribution of participant characteristics for phase 2 (preference testing) and phase 3 (pictogram validation) of the study.

Characteristics	Mean ± Standard Deviation or n (%)	
	Phase 2 (preference testing) (N = 100)	Phase 3 (pictogram validation) (N = 278)
Age, years		
Mean	68.4 ± 6.13	68.8 ± 5.45
60–64	28 (28.0)	65 (23.4)
65–69	32 (32.0)	90 (32.4)
70–74	27 (27.6)	83 (29.9)
75–87	13 (13.0)	40 (14.4)
Gender		
Female	67 (67.0)	142 (51.1)
Ethnicity		
Chinese	88 (88.0)	259 (93.2)
Malay	4 (4.0)	8 (2.9)
Indian	7 (7.0)	9 (3.2)
Others (Eurasian/ Ceylonese/ Javanese)	1 (1.0)	2 (0.7)
Highest education level		
No formal education	5 (5.0)	13 (4.7)
Primary	11 (11.0)	45 (16.2)
Secondary	37 (37.0)	91 (32.7)
Vocational/ Institute of Technical Education	1 (1.0)	12 (4.3)
Junior College/ Polytechnic	23 (23.0)	67 (24.1)
University and above	23 (23.0)	50 (18.0)
Employment history		
Ever employed	97 (97.0)	278 (100.0)
Housing type		
1- and 2-room government-built flat	2 (2.0)	2 (0.7)
3-room government-built flat	19 (19.0)	29 (10.4)
4- and 5-room government-built flat	66 (66.0)	170 (61.2)
Private housing	13 (13.0)	65 (23.4)
Studio apartment	0 (0.0)	12 (4.3)
Living arrangement [a]		
Alone	7 (7.0)	33 (11.9)
With spouse, no children	27 (27.0)	90 (32.4)
With children, no spouse	15 (15.0)	27 (9.7)
With spouse and children	37 (37.0)	99 (35.6)
With others	14 (14.0)	29 (10.4)
Abbreviated Mental Test score [b]	–	4.82 ± 0.43
Number of prescription medicines	2.81 ± 2.25	3.40 ± 2.31 [c]
Polypharmacy (≥5 prescription medicines)	19 (19.0)	66 (24.3) [c]
Language of interview		
English only	72 (72.0)	134 (48.2)
Mandarin Chinese only	21 (21.0)	90 (32.4)
Malay only	2 (2.0)	0 (0.0)
Tamil only	1 (1.0)	0 (0.0)
English and one of the other languages	3 (3.0)	54 (19.4)
Mandarin Chinese and one other dialect	1 (1.0)	0 (0.0)
Mode of interview		
Remote	100 (100.0)	131 (47.1)
In-person	–	147 (52.9)

[a] Each living arrangement category includes those with or without a domestic helper.
[b] There were two interview modes in phase 3. Participants interviewed in-person were administered the 10-item Abbreviated Mental Test (AMT), while for participants interviewed remotely, it was feasible to administer only 5 questions of the AMT. Therefore, the AMT scores reflect the number of correct responses to only the 5 questions that were administered to all participants.
[c] In phase 3, six participants reported "don't know" for "number of prescription medications". Thus, N for "number of prescription medicines" and "polypharmacy (≥5 prescription medicines)" is 272.

9186 [24], which guides the development of graphical symbols that can be correctly understood by users when no accompanying text is presented. It provides a method for assessing how well a variant of a graphical symbol communicates its intended message. A newer version of the ISO standard 9186 recommends the use of transparency testing when evaluating a maximum of 15 sets of pictograms, with up to three pictogram variants contained within each set [20]. Although there were two to three pictogram variants within each set in our current study, it was not feasible to adhere to the newer ISO recommendations as we assessed 26 sets of pictogram variants in total. Furthermore, transparency testing requires audio-recording, verbatim transcription, translations and grading of participant responses [9]. In comparison, preference testing is less resource-intensive and has a lower respondent burden.

During preference testing, participants were probed on their reasons for choosing a particular pictogram variant. Their responses, presented in Supplementary Table 3, affirmed that participants did assess the variants in relation to key concepts addressed in the pictogram validation procedure, which included comprehensibility, representativeness of the intended meaning and cultural acceptability. For example, one participant expressed that the cross in variant 2 of "seek medical advice" is a "universal sign for hospital and medical services", and thus easily comprehensible. Similarly, participants found variant 2 of "take with food" to be culturally appropriate as rice is a staple food for Asians, including Singaporeans, and a participant voiced that the hand on the forehead in variant 3 of "fever" was "well-representative of the concept". This indicates that preference testing can be a holistic and efficient method to evaluate the comprehensibility and acceptability of variants, despite its relative straightforwardness or simplicity.

4.1.2. Validation of the most-preferred pictogram variants

In our previous study that assessed 52 FIP pictograms among older Singaporeans with limited English proficiency, only 20 (38.5%) pictograms were deemed as valid or partially valid [9]. In this study, contextual redesigning and selection of the most-preferred variant of 27 FIP pictograms, which had initially failed to achieve validity in our previous study, resulted in the validation of 15 (55.6%) of the 27 pictograms.

Even among the remaining 12 redesigned pictograms that were not valid, their transparency and translucency scores were generally higher than what were observed for the original FIP version of the pictograms [9]. The iterative, user-centred pictogram development process adopted in this study likely contributed to the redesigned pictograms having better clarity, representativeness, and cultural fit for older Singaporeans. In addition, the proportion of pictograms being comprehended per participant increased from 52.0% in the previous study [9]. to 64.7% in the current study. This improvement could partially be attributed to the lower ages and better educational profiles of participants in this study, compared to the previous study.

Three redesigned pictograms did not show improved transparency and/or translucency scores compared to the original FIP versions [9]. For instance, the redesigned version of "difficulty in breathing" had both poorer transparency and translucency scores compared to the FIP version. Some participants misinterpreted the pictogram for "cough" or "COVID-19". This may be because of the heightened awareness of respiratory symptoms [25] during the time of the study, which coincided with the COVID-19 pandemic. Relatedly, in the context of the redesigned pictogram "tremors or shaky hands", several participants had misinterpreted the pictogram to mean "hand washing". The redesigned pictograms for "half tablet" and "take until finished" had slightly improved transparency scores but poorer translucency scores, compared to the FIP version [9]. We found it challenging to conceptualise a pictorial representation for "take until finished", due to safety concerns that individuals might misinterpret it for "take until finished *at one go*". Other studies have also reported relatively low comprehensibility rates for pictograms depicting "complete the course", ranging between 0% to 52.2% [8,9,21]. However, in one study, redesigning the pictogram "finish all this medication" increased comprehensibility from 15% to over 70% [26]. Overall, it might be difficult to further improve the comprehensibility and/or representativeness of pictograms depicting medication-related concepts that are complex or nuanced.

The majority of the redesigned pictograms depicting precautions achieved partial validity or validity (77.8%), providing evidence of the potential to improve such pictograms through modification. A previous study reported that precautionary and indications or side effects pictograms did

Table 3
Proportion of participants with a *correct* response (transparency), proportion of participants rating representativeness as ≥5 (translucency), and validation status for 27 redesigned pictograms tested in phase 3.

Redesigned pictogram's intended meaning (number of participants assigned to the pictogram)	Proportion (%) of participants with a *correct* response (transparency)	Proportion (%) of participants rating *representativeness as* ≥ *5* (translucency)	Validation status [a]
Pictogram category: Dose and route of administration (3 pictograms)			
Apply to affected area (n = 103)	90.3	85.4	Valid
Insert 1 suppository (n = 102)	89.2	89.2	Valid
Half a tablet (n = 101)	57.4	73.3	Not valid
Pictogram category: Precautions (9 pictograms)			
Do not drive (n = 104)	97.1	98.1	Valid
Take with food (n = 104)	96.2	89.4	Valid
Keep out of reach of children (n = 104)	91.3	95.2	Valid
Shake (n = 105)	80.0	91.4	Valid
Do not eat grapefruit or drink grapefruit juice (n = 102)[b]	76.5	92.2	Valid
Take 1 hour before food (n = 99)[b]	71.7	78.8	Partially valid
Do not crush (n = 102)	69.6	73.5	Partially valid
Seek medical advice (n = 104)	26.0	86.5	Not valid
Take until finished (n = 103)	2.9	39.8	Not valid
Pictogram category: Indications or side effects (15 pictograms)			
Fever (n = 103)	98.1	99.0	Valid
Muscular pain (n = 100)	95.0	87.0	Valid
Drowsiness (n = 103)	88.3	86.4	Valid
Sensitive to sunlight (n = 101)	81.2	80.2	Partially valid
Constipation (n = 104)	74.0	80.8	Partially valid
Weight gain (n = 103)	67.0	75.7	Partially valid
Tremors or Shaky hands (n = 105)	64.8	72.4	Not valid
Diarrhea (n = 103)	57.3	90.3	Not valid
Giddy when getting up (n = 104)	52.9	85.6	Not valid
Gastric or Reflux (n = 103)	52.4	64.1	Not valid
Ringing in ears (n = 103)	48.5	86.4	Not valid
Difficulty in sleeping (n = 102)	48.0	67.7	Not valid
Blurred vision (n = 104)	40.4	79.8	Not valid
Confusion (n = 104)	19.2	67.3	Not valid
Difficulty in breathing (n = 103)	13.6	43.7	Not valid

[a] *Valid*: ≥ 66% participants with a *correct* response without being informed of its intended meaning & ≥ 85% participants with a rating of ≥ 5, when asked to rate how well the pictogram represents its intended meaning on a scale of 1 to 7; *Partially valid*: ≥ 66% participants with a *correct* response without being informed of its intended meaning & < 85% participants with a rating of ≥ 5, when asked to rate how well the pictogram represents its intended meaning on a scale of 1 to 7; *Not valid*: < 66% participants with a *correct* response without being informed of its intended meaning.
[b] These two pictograms contain English text, "grapefruit" and "wait 1 hour". The English text was translated into Mandarin Chinese, Malay and Tamil. Participants who preferred to read in a language other than English were shown the pictogram that had "grapefruit" and "wait 1 hour" translated in their preferred language.

Table 4
Association of participant characteristics with the proportion of assigned redesigned pictograms correctly comprehended (transparency) (0 to 100%) in phase 3: Linear regression (N = 272).

Characteristics	Unadjusted regression coefficient (95% CI)	Adjusted regression coefficient (95% CI)
Age, in years	**−0.69 (−1.09, −0.28)**	**−0.59 (−1.02, −0.17)**
Gender – Male *(Ref: Female)*	−1.11 (−5.62, 3.41)	−0.34 (−5.07, 4.39)
Highest education level *(Ref: No formal education or primary)*		
Secondary	3.93 (−2.15, 10.00)	1.24 (−5.81, 8.29)
Tertiary	**11.78 (5.55, 18.01)**	**9.19 (1.99, 16.39)**
University and above	**15.68 (8.75, 22.60)**	**10.77 (2.35, 19.20)**
Housing *(Ref: 2-room flat or studio apartment)*		
3-room flat	5.00 (−7.17, 17.17)	4.61 (−7.51, 16.73)
4- and 5-room flat and Private	6.82 (−3.41, 17.05)	1.18 (−9.08, 11.44)
Abbreviated Mental Test score [a]	2.48 (−2.80, 7.77)	0.04 (−5.16, 5.25)
Polypharmacy – Yes *(Ref: No)*	1.99 (−3.27, 7.26)	2.49 (−2.72, 7.70)
Language of interview *(Ref: English only)*		
Mandarin only	**−8.30 (−13.35, −3.24)**	1.17 (−6.38, 8.72)
English and 1 other language (Mandarin, Malay or Tamil)	−3.46 (−9.42, 2.49)	1.40 (−5.32, 8.12)
Mode of interview *(Ref: Remote)*		
Face-to-face	**−9.57 (−13.88, −5.19)**	−6.11 (−12.61, 0.39)
R^2	–	*0.146*

CI: Confidence interval; FIP: International Pharmaceutical Federation; Ref: reference.
[a] Higher score indicates better cognitive ability (Range: 2 to 5).

not show good understanding among older adults [14]. Our previous study affirmed this claim – only 18.2% of assessed precautionary pictograms achieved validity, compared to pictograms depicting dose and route of administration (69.2%), dosage frequency (60.0%) and indications or side effects (26.1%) [9]. Although pictograms depicting indications or side effects showed a slight improvement from our previous study, they remained the most poorly understood, with only 40.0% of such pictograms being validated or partially validated.

4.1.3. Participant characteristics associated with pictogram comprehension

This study noted that poorer pictogram comprehension was associated with older age and lower education level, similar to our previous study [9]. This underscores the importance of medication counselling in ensuring that older and less educated patients comprehend pharmaceutical pictograms. Polypharmacy was associated with better pictogram comprehension performance in our previous study; however, this association was not observed in this current study. The need to take, use or interact with more types of medications did not seem to influence participants' understanding of medication-related pictograms in a consistent way.

4.2. Innovation

The validated redesigned pictograms in our study have undergone rigorous testing to ensure their comprehensibility and acceptability by older Singaporeans. These newly developed pictograms can be effective in facilitating patient understanding of medication information. Healthcare institutions in Singapore should strongly consider incorporating validated pictograms from this study, and our previous study, [9]. into relevant patient education materials such as PMLs. In addition, due to the lack of space on PMLs, pictograms depicting precautions and side effects could be provided on physical or digital patient information leaflets (PILs), patient medication lists and any additional printouts.

Besides increasing patient access to medication information through the inclusion of validated pictograms on various medication information sources, healthcare institutions and pharmacy staff also play an important role in ensuring the safe use of pictograms in clinical settings, in three ways. First, pictograms should be used in conjunction with clear and simple text [4,27,28]. A previous study conducted among older Singaporeans found that providing pictograms alongside English-only text on PMLs yielded a lower understanding of PMLs compared to including both pictograms with bilingual text on PMLs, among older adults [29]. In Singapore, where 53% of older adults are unable to read in English, [30]. the provision of accompanying text in multiple languages, such as Chinese, Malay and Tamil, appears to be crucial in achieving a better understanding of medication information. This should not be difficult to implement as the translations for the accompanying text of the pictograms are already available through our study. Second, the use of validated pictograms and accompanying text should be standardised across healthcare institutions at the national level. On a related note, a previous study highlighted that inconsistency in the medication information provided on PMLs dispensed by different clinics, but for the same medication, caused confusion for older adults [31]. Therefore, similarly, pharmaceutical pictograms used on PMLs, or health information materials should be provided in a consistent design across various healthcare providers to minimise confusion and misinterpretation. Third, pharmacy staff and pharmacy students should be educated on the importance of pictograms for communicating medication information to low-literate older patients and be trained to use these pictograms effectively during medication counselling. Prior studies or reviews have reported that the use of pictograms in combination with verbal instructions can improve comprehension and recall of health information [32-34]. These can help to embed safe and effective use of patient-centred pictograms in pharmaceutical care delivery, benefitting older and low-literate populations in Singapore.

The paradigm shift in healthcare delivery towards patient-centred care is transforming the role of patients, who are expected to take more responsibility in managing their health, sharing their perspectives, and becoming involved in re-shaping healthcare delivery [35]. It is recognised that understanding patient preferences and experience can bring about improvements in healthcare service delivery and outcomes [36]. This study used a user-centred procedure to redesign pictograms, enabling the voices of older adults to be incorporated in the design process. This approach may have contributed to the improvement in comprehensibility and translucency scores that was observed for a majority of the redesigned pictograms. Second, engagement of a professional graphic designer firm helped enhance the clarity of the graphic elements of the redesigned pictograms. Third, the detailed phases described in our methods can help to streamline processes for developing culturally-appropriate pictograms, which can contribute to advancing the field of pictogram-based research [18]. Also, in our previous study, only participants with limited English proficiency were recruited. For this study, we also included older adults who were proficient in English, resulting in a more inclusive sample.

There are some limitations that should be considered when interpreting the findings of this study. Firstly, this study was conducted during the COVID-19 pandemic, where tighter measures were in place, warranting the need for Zoom® interviews. Thus, we acknowledge that this mode of recruitment is not fully inclusive and older adults with low digital literacy may have been excluded. On a related note, the inclusion of participants was not based on random sampling, due to the mode of recruitment. Next, we also recognise that health literacy of an individual can influence the comprehension of pharmaceutical pictograms [10], however, this was not measured in our study, Nonetheless, the use of pharmaceutical pictograms by itself will mitigate the impact of low health literacy. We also acknowledge that some of the redesigned pictograms did not achieve validity in our study. Nevertheless, the second-most preferred variant, which was also developed in this study, may be considered for validation testing in future studies.

5. Conclusion

A user-centric approach was used to develop, evaluate, and validate pictograms among older Singaporeans. A total of 77 variants were developed based on FIP pictograms. Subsequently, 27 context-specific variants were chosen by older adults as their most preferred ones, to be re-validated. A total of 15 redesigned pictograms were successfully validated. Along with the 20 original FIP pictograms validated in our previous study [9], the redesigned validated pictograms can be incorporated into relevant patient information materials in clinical practice.

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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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pecinn.2022.100116.

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