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VERBAL AND VISUAL INTERPRETATION OF PICTURES EMBEDDED WITH RELEVANT SIGNS AND SYMPTOMS OF EYE PROBLEMS

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Abstract: There is a recognised need for a questionnaire playing a crucial role in eye care. Substantial research has been undertaken on the role of a questionnaire assessing the vision-related quality of life. However, the need for pictures to be embedded as a part of the questionnaires has not been recognised. This study investigated the verbal and visual interpretation of pictures about signs and symptoms of eye problems. 60 subjects aged 18 to 40 years old were recruited using convenient sampling in this cross-sectional study. Sixteen pictures representing three domains (physical signs, behavioural signs and visual-related activity) were included. The verbal interpretation was recorded for each picture. The visual interpretation was recorded as fixation count and duration using a heat map for three pictures representing each domain. All pictures (100%) under the physical signs category provided a high percentage (more than 80%) of correct verbal responses. A significant difference in the verbal responses was found between gender and two different levels of education for behavioural signs and visual-related activity pictures ($p<0.05$). Significantly longer fixation duration was found among respondents who provided incorrect verbal responses compared to correct verbal responses ($p<0.05$). A simple picture with direct information like ocular misalignment was more interpretable than a picture with abstract information like 'glare' and 'writing up and downhill'. Both verbal and visual interpretations of the picture are closely correlated. Therefore, selecting pictures of eye care questionnaires for the general population should consider a minimum cognitive load to improve interpretability.

Keywords: Questionnaire, picture, sign, symptom, visual interpretation.

Introduction

Difficulties interpreting ambiguous wording and terminology in questionnaire items might affect reading performance and comprehension (Davidson *et al.*, 2017). Reading comprehension can be difficult for people with low literacy skills. The World Health Organization reported that many people with low literacy skills even in high-income countries (Jolly, 1999). Complementing pictures in textual material improved attention and comprehension of health education material (Houts *et al.,* 2006). The pictorial questionnaire used in a study on food behaviour facilitates intercultural research regardless of language influences (Ammann *et al.,* 2018). The use of a picture-assisted response scale in a single-item questionnaire provided a rapid assessment of the signs and symptoms of dry eye (Grubbs *et al.,* 2014).

Generalisation in pictorial interpretation corresponds to the real world could be made from highly iconic picture appearance (Ganea *et al.,* 2008). People can perceive the same picture differently based on the interpretive theory of mind. Their interpretation can be influenced by gender (Kret & De Gelder, 2012; Abbruzzese *et al.,* 2019) and level of knowledge (Cooper *et al.,* 2009; Mayer & Moreno, 2012). Types of pictures also affect comprehension of health education materials (Moll, 1986). Line drawing and colour pictures facilitate comprehension more than shaded drawing, photographs and monochrome images (Moll, 1986). Despite widely used images and graphics in healthcare education, the mechanism underlying cognitive processing of information retrieval in healthcare education material is still lacking (Houts *et al.,* 2006). The need for pictures to be embedded as a part of questionnaires has not been recognised. The use of inappropriate images might interfere with reading comprehension (Filippatou & Pumfrey, 1996).

Signs and symptoms of eye problems can generally be sorted into three main types: (i) Physical signs (such as red eye, swollen eye and squint), (ii) Behavioural signs (such as responding to glare, headache and eye pain) and (iii) Perceived limitation in vision-related activity (such as write up and downhill, skip word when reading and bumping to object when moving around). The characteristic of pictures can be diverse from simple to complex, relying on the relevant signs and symptoms of eye problems used; therefore, selecting an appropriate image to be included in the eye care questionnaire is essential.

Interview procedures and think-aloud methods are frequently used in health research to probe information (Joffer *et al.,* 2016). However, such methods might suffer validity issues (Charters, 2003). The use of eye-tracking technology encompasses its ability to recode real-time activities and is more promising for analysing the cognitive process in information processing (Rayner, 2009). Eye fixation time is correlated with cognitive performance (Canham & Hegarty, 2010). Eye-tracking measurement might support and validate findings generated from the interview method. Therefore, this study was conducted to provide qualitative and quantitative data on what characteristics of pictures related to signs and symptoms of eye problems can affect interpretability and how picture interpretation is affected by the population at different levels of education and gender.

Materials and Methods

The objective of this study was to determine the interpretability of pictures related to signs and symptoms of eye problems and to compare the interpretation of pictures on signs and symptoms of eye problems among adults according to their level of education and gender based on verbal responses. Further analysis was made to quantify the fixation duration and heat map pattern of respondents during the interpretation of the pictures. Before data collection, pre-defined characteristics of drawings were first produced as described in the previous publication (Chen *et al.*, 2021). Three domains with 16 sub-domains were recognised (Table 1) from a thorough review of items in the existing questionnaire for paediatric eyecare targeting four vision

Table 1: Domains and sub-domains to formulate pre-defined characteristics for drawings according to target vision clusters

Domains	Collections of Sub-domains	Target Vision Clusters
Physical signs	• Tearing	Ocular health
	• Redness	Ocular health
	• Eye discharge	Ocular health
	• Swollen	Ocular health
	• Deviation (squint)	Physiological
Behavioural sign	• Rub	Physiological
	• Reaction to light (glare)	Physical
	• Double vision	Physiological
	• Headache/dizzy	Physiological
	• Eye pain	Physiological
	• Lose concentration	Physiological
Visual-related activity	• Watch TV	Physical
	• Read/copy from the board	Physical
	• Reading or computer use	Physical
	• Writing	Perceptual
	• Mobility and navigation	Perceptual

clusters (Chen *et al.*, 2021). The physical signs emphasise the abnormal physical appearance of the eyes. Behavioural signs refer to abnormal behaviour to compensate for visual symptoms while visual-related activity describes any sign of a problem when performing activities that require visual demand.

A total of 60 subjects were recruited through convenience sampling in this cross-sectional study. The respondents (aged 18 to 40 years) were matched in gender. They were divided into two groups based on their highest level of education: [Group 1: Secondary schools (n=30) and Group 2: College and university (n=30)]. Persons with visual impairment (distance vision less than 6/12 or near vision less than N8) or having any ocular alignment or ocular movement disorders (such as nystagmus) were excluded from this study. A person with cognitive or communication problems was also excluded. Written informed consent was obtained from each subject before data collection. The pictures were compiled into a random sequence in a PowerPoint presentation and presented using a desktop screen at a viewing distance of 50 cm. Respondents were required to wear their distance and near correction if needed. All respondents were required to verbally interpret each picture shown on each slide based on their perception without additional cues. The correct response toward each picture was analysed descriptively. A chi-square (χ^2) analysis was performed to compare the correct answers towards the interpretation of pictures between gender and level of education. This study was approved by the institutional ethics committee (Ref.: 600-IRMI (5/1/6) REC/85/17) following the declaration of Helsinki.

Further evaluation was made on 30 respondents (aged between 18 and 40 years) for three pictures (glare, squint, write-up and downhill) representing the three domains. The pictures were selected based on ambiguous wording used in the existing questionnaires for every three domains identified in the previous evaluation to assess the potential of pictures as an alternative to textual description (Mcculloch *et al.,* 2007; Hatt *et al.,* 2010; Abu Bakar *et al.,* 2012). Item in the existing questionnaires used the word "screw up his/her eyes" to explain "glare", "my eyes go in and out" for "ocular misalignment" and "writes up and downhill" for "problem in writing". The visual fixation of each respondent was monitored using Dikablis Eye Tracker. This instrument enables the study of visual perception and behaviour in normal and natural environments. It was built with a spectacle mounted to provide minimal interference in evaluating the subject's natural viewing (Kasneci *et al.,* 2017). The pictures were viewed on an LG black desktop monitor (Display area: Horizontal; 16.8", vertical; 12.0", diagonal; 20.1") at a 50 cm distance. Respondents were required to wear their distance and near correction if needed. Each respondent was first calibrated on the eye tracker system. In the calibration procedure, each respondent was instructed to fixate on a blue cross at the centre of the screen, followed by four dots at each edge to calibrate the pupil's location and Area of Interest (AOI) (Figure 1).

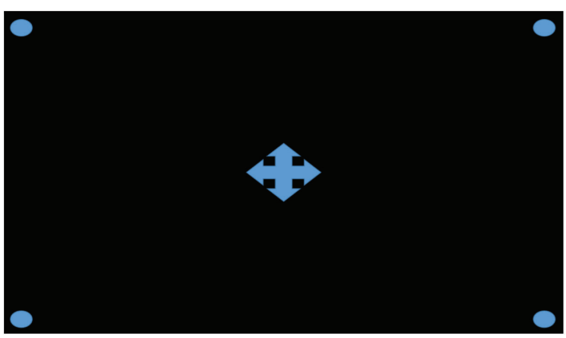


Figure 1: Picture used in the calibration of the Dikablis Eye Tracker

The purpose of the calibration process is to allow the eye tracker to associate the viewer's pupil data with the location of the stimulus. During data collection, respondents were required to interpret the main message of the images shown verbally. Heat map pattern and fixation duration of eye movement were assessed using the Dikablis eye tracker. The averages of fixation duration were determined to support the analysis of the time required in information processing (Djamasbi, 2014). An independent t-test was used to analyse the fixation duration between those who responded correctly and those with incorrect responses. Qualitative analysis of the location of fixation for each picture for each subject was based on a heat map pattern for in-depth investigation of information processing, comparison was made with verbal responses. A heat map represents fixation count or duration at a specific location through colour coding (Djamasbi, 2014). The area with the longer and many fixations was typically depicted with a warm colour (e.g., red). In contrast, those with a lower number of fixations and duration were represented by colder colours.

Results and Discussion

Half of the 16 drawings have more than 75% correct verbal responses or descriptions that match the characteristics and target conditions. Analysis of the best pictures for the four visual clusters showed that the highest percentage (100%) of correct verbal responses was the picture that represented red-eye. In contrast, the lowest percentage (36%) represents writing up and downhill (Table 2).

Physical signs of eye problems are more observable by non-eye care professionals compared to behavioural signs (Chen *et al.,* 2020). A previous study on parents who reported signs and symptoms of eye problems among their offspring showed that more than 80% of parents were able to report physical signs of eye problems among their offspring compared to only 50% of parents able to report behavioural signs and symptoms (Chen *et al.*, 2020). In this

Table 2: Correct verbal response toward interpretation of four pictures among 60 respondents

Domain		Pictures	Percentage of Match[a] (%)	Target Vision Clusters
Physical signs	1)	Tearing	83%	Ocular health
	2)	Red-eye	100%	Ocular health
	3)	Eye discharge	95%	Ocular health
	4)	Swollen eye	93%	Ocular health
	5)	Ocular misalignment	97%	Physiological
Behavioural signs	6)	Eye rubbing	75%	Physiological
	7)	Glare	57%	Physical
	8)	Double vision	63%	Physiological
	9)	Headache/dizzy	90%	Physiological
	10)	Eye pain	63%	Physiological
	11)	Lose concentration	38%	Physiological
Visual-related activity	12)	Watch TV very close	62%	Physical
	13)	Read/copy from the board	72%	Physical
	14)	Near visual task problem	57%	Physical
	15)	Write up and downhill	36%	Perceptual
	16)	Bumping into object	98%	Perceptual

[a]Percentage of participants with correct descriptions as pre-defined characteristics or correct target

study, all pictures (100%) under the physical signs category provided a high percentage (more than 80%) of correct verbal responses as they represented a common ocular problem that can be observed by many people (Helveston, 2010). A majority (more than 80%) of the interpretation of pictures related to behavioural signs and visual-related activity provided incorrect verbal responses. This finding supported that integrating pictures that are difficult for the observer to understand may not convey the message rather often incorrectly interpreted (Filippatou & Pumfrey, 1996). Therefore, the physical signs of ocular problems might be more suitable to be translated into a picture than behavioural signs and visual-related activity for eyecare questionnaires.

Comparison analysis on factors that might influence pictorial interpretation showed a significant difference in pictorial interpretation between genders ($p<0.05$) for two pictures [read/copy from the board (χ^2=4.022, p=0.045) and double vision (χ^2=4.593, p=0.032)]. A significant difference in the verbal responses was also found between different levels of education for two pictures [write up and downhill (χ^2=8.864, p=0.003) and watching TV very close (χ^2=7.200, p=0.007)] while no significant difference for other pictures as shown in Table 3.

Table 3: Association of correct verbal responses and respondents' level of education and gender (n=60)

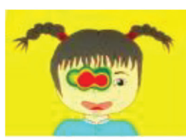
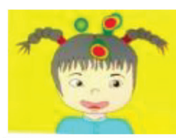
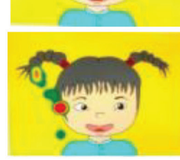
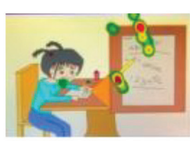
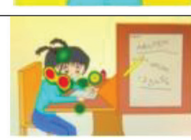
Pictures	Levels of Education				Gender			
	Correct Response (%)		Chi-square (X^2)	P-value	Correct Response (%)		Chi-square (X^2)	P-value
	Secondary School (n=30)	College or University (n=30)			Male (n=30)	Female (n=30)		
Tearing	80%	87%	0.480	0.488	80%	87%	0.480	0.488
Watch TV very close	47%	77%	5.711	0.017*	67%	57%	0.635	0.426
Eye rubbing	60%	90%	7.200	0.007*	73%	77%	0.089	0.766
Glare	50%	63%	1.086	0.297	47%	67%	2.443	0.118
Near task	57%	57%	0.000	1.000	57%	57%	0.000	1.000
Read/copy from the board	67%	77%	0.739	0.390	83%	60%	4.022	0.045*
Eye pain	53%	77%	3.590	0.058	70%	60%	0.659	0.417
Write up and downhill	17%	53%	8.864	0.003*	30%	35%	0.659	0.417
Lose concentration	33%	43%	0.635	0.426	37%	40%	0.071	0.791
Squint	93%	100%	2.069	0.150	100%	93%	2.069	0.150
Red-eye	100%	100%	Not calculated because the value constant		100%	100%	Not calculated because the value constant	
Bump into object	97%	100%	1.017	0.313	100%	97%	1.017	0.313
Headache	90%	90%	0.000	1.000	90%	90%	0.000	1.000
Double vision	57%	70%	1.148	0.284	77%	50%	4.593	0.032*
Swollen eye	93%	93%	0.000	1.000	93%	93%	0.000	1.000
Eye discharge	90%	100%	3.158	0.076	93%	97%	0.351	0.554

*P-value<0.05

Interpretation of behavioural signs and visual-related activities pictures in this study was influenced by gender and level of education. Discrepancies in interpretation between genders might be related to emotional expression in the pictures (Abbruzzese *et al.,* 2019). Therefore, pictures representing signs and symptoms of ocular problems should not include expressive features. This study also revealed the discrepancy in the ability to interpret pictures that link to behavioural signs and visual-related activity between those in the two different levels of education to support that perceptual interpretation is related to the knowledge of the viewers (Mayer & Moreno, 2012). Through the principle of knowledge, people with higher prior knowledge learned better than people with low prior knowledge (Mayer & Moreno, 2012). A study on the interpretation of diagnostic imaging showed that novice observers might not generate hypotheses from visual images despite scanning more of an image. At the same time, the expert might focus on relevant areas, generate ideas and make a complex decision based on a mental scheme of salient image features (Garlatti & Sharples, 1998). A highly correct response toward physical sign pictures suggested that they can be easily interpreted by adults regardless of their level of education.

Qualitative analysis of the heat map pattern revealed significant differences in fixation count and duration between those who provided correct and incorrect verbal responses (Table 4).

Table 4: Comparison of heat map patterns between subjects who provided correct and incorrect responses

Pictures	Heat Map Pattern	
	Correct Responses	Incorrect Responses
Glare  Percentage of correct responses (n=30): 30%	 	 
Ocular misalignment  Percentage of correct responses (n=30): 93%	 	 
Write up and downhill  Percentage of correct responses (n=30): 40%	 	 

Heat map pattern among those who provided correct answers for ocular misalignment was found to accumulate at the specific abnormal eye area. In contrast, the pattern was more diverse and not gathered to particular areas for glare, write-up and downhill pictures. A heat map pattern was accumulated in the irrelevant area among those who provided incorrect responses for all pictures. The percentage of correct verbal answers among respondents involved in the eye-tracking assessment was relatively higher (93%) for ocular misalignment pictures. A lower percentage of correct responses was found for ‘glare’ and ‘writing up and downhill’ pictures (30% and 40%, respectively).

Quantitative analysis of fixation duration (Table 5) showed that fixation duration for interpretation of the pictures ranges from 1,530 milliseconds to 4,269 milliseconds. Relatively longer fixation duration was found among those who provided correct responses compared to incorrect answers for ocular misalignment pictures. In contrast, a relatively longer fixation duration was found among respondents who provided incorrect responses compared to correct responses for ‘glare’ and ‘writing up and downhill’ pictures, although the difference is only significant for ‘glare’ pictures. At the same time, there was no significant difference for other pictures.

Heat map pattern among those who responded correctly for physical sign pictures accumulated at specific abnormal eye areas suggests that simple drawings are most effective in facilitating comprehension (Houts *et al.,* 2006). Relatively longer fixation duration found among those who provided correct responses compared to incorrect answers for direct sign pictures indicated a higher level of attention and interest (Djamasbi, 2014). Respondents with prior knowledge regarding the message of the picture were reported to spend more time within the area of interest before decision-making to support that area with a longer fixation duration for physical sign picture provide essential features for the observer to generate enough ‘hypotheses’ regarding the objective of the picture (Cooper *et al.,* 2009). Behavioural signs and visual-related activity pictures portray many features, including unintended features that may attract diverse attention away from essential elements that provide information for interpretation (Djamasbi, 2014). A significantly longer fixation duration found among those who offered incorrect responses than correct answers for behavioural signs in this study indicated confusion. The observer may fixate on an AOI longer if they cannot find the desired information (Cooper *et al.,* 2009; Djamasbi, 2014). A previous study also showed that irrelevant features impair the performance in picture interpretation to suggest that effective graphical displays should not display more information than is required for the specific task (Canham & Hegarty, 2010). These findings indicated that one particular eye of the physical sign area is sufficient for information retrieval in pictures related to signs and symptoms of eye problems.

Table 5: Comparison of duration of fixation between correct and incorrect responses (n=30)

Picture	**Response**	**Percentage (%)**	**Time in Milliseconds (±standard deviation)**	**t-test**	**P-value**
Glare	Incorrect	70	3652.3 (±1041.6)	2.382	0.024*
	Correct	30.0	2698.6 (±907.0)		
Ocular misalignment	Incorrect	7.0	1530.0 (±567.0)	-1.154	0.135
	Correct	93.0	3100.0 (±1418.5)		
Write up and downhill	Incorrect	60.0	4269.9 (±1596.0)	2.009	0.054
	Correct	40.0	3074.7 (±1597.1)		

*P-value<0.05

Conclusion

Identification of the appropriate characteristics of pictures embedded with signs and symptoms of eye problems through the implementation of an eye-tracking device is a beneficial prior selection of appropriate pictures to be included in the eye care questionnaires. Pictures that represented a physical sign of an eye problem might be more suitable for the eye care questionnaire than behavioural symptoms and visual-related activity pictures. A physical sign picture with specific features of the eye area in the eye care questionnaire might be sufficient to convey information regarding eye health conditions. The existence of too many irrelevant features including emotional elements might negatively affect the interpretation of pictures.

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