COMPREHENSION TESTS AND EYE MOVEMENTS IN READING MATHEMATICS: VERBAL COMPARING WITH EQUATION

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Introduction

- Mathematical symbol, equation, and figure are used in some newspapers, magazines and professional documents.
- Ö sterholm (2006) found high school and university students who read group theory text written without symbols had better comprehension than those readers who read the similar content written with symbols. It meant mathematical texts using symbols demand a special skill for reading comprehension.
- The purpose of this study was to investigate the effect of different representation of verbal and equation on reading comprehension and eye movements.

Method

Participant

- Forty-two university students who did not major in mathematics.
- All participants had normal or corrected vision and passed the procedures of calibration and validation of the eye tracker.

Materials

- The materials were two texts in Chinese rewritten from popular science books, and each text had a graph.
- The topics were “how to figure out the Earth radius” and “how to estimate the height of an island”. Both texts had two versions written with verbal (eg. the arc length is equal to the central angle multiply by radius) or equation (eg. $d = \theta \times r$) in the key areas, but other parts were the same (Figure 1).
- There were 5 and 7 key areas in the two texts.

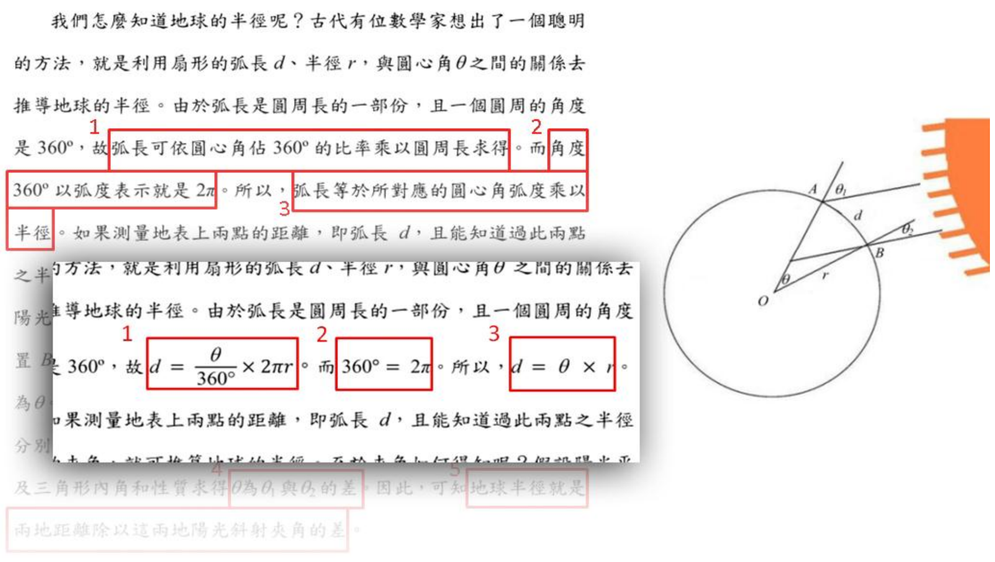

Figure 1. The different key areas of text (upper) and equation (lower) – an example of the earth topic

Procedure

- Eye movements were recorded by an Eyelink 1000 with a sampling rate of 1000HZ.
- 42 participants were randomly assigned to one version (Verbal : 20 ； Equation : 22).
- After the practical article was presented, participants read two texts without time limited. Order of texts were counterbalance.
- After reading each text, participants were asked to evaluate the degree of difficulty and complete a true/false test, their response time of test was recorded simultaneously.

Result

Students had similar comprehension whether read the version of verbal or equation.

- There were no significant differences between two versions on difficult rating, reading comprehension, and response time of comprehension test (Table 1).

Table 1: Means and (*SD*) of behavior performance and eye movement data

		verbal		equation		*F*-value
		M	(*SD*)	*M*	(*SD*)	
difficult rating (1~6)	earth	4.00	(1.19)	3.61	(1.03)	1.75
	island	4.25	(0.84)	4.04	(1.04)	0.69
accuracy of reading comprehension	earth	0.73	(0.15)	0.80	(0.15)	2.68
	island	0.82	(0.16)	0.85	(0.18)	0.31
response time per item (sec.)	earth	24.26	(8.73)	27.49	(14.17)	1.06
	island	22.41	(12.42)	23.64	(11.06)	0.15
key areas TVD (sec.)	earth	42.61	(30.91)	50.22	(38.87)	0.49
	island	84.17	(53.48)	98.68	(69.51)	0.49
percentage of fixation time on graph (%)	earth	24	(12)	45	(13)	28.36***
	island	44	(9)	56	(9)	16.29***

*** : $p < .001$

Eye movements showed readers consumed more time on processing equation representation.

- Readers who read the version of equation representation had more reading time than whom read the version of verbal representation, and the tendency was similar with the key areas showing readers spending more total viewing durations (TVD) on the equation version (Table 1).

Readers of the equation version need to refer to graphs more often.

- Readers who read the equation version had higher percentage of fixation time on graphic section than those readers read the version of verbal representation, approximately 40% versus 30% , the Earth : F (1, 40) = 28.36, $p < .001$ ； island : F(1, 34) = 16.29, $p < .001$ (Table 1).
- Yellow baseline was key areas. Red arrow was the most likely scan path. After participants read area of Green tick, their focus moved to graph area. After transition matrix by Markov analysis, the result indicated that participants use to focus on next text area when verbal representation in key areas. However, participants used to focus on graph area when equation representation in key areas.

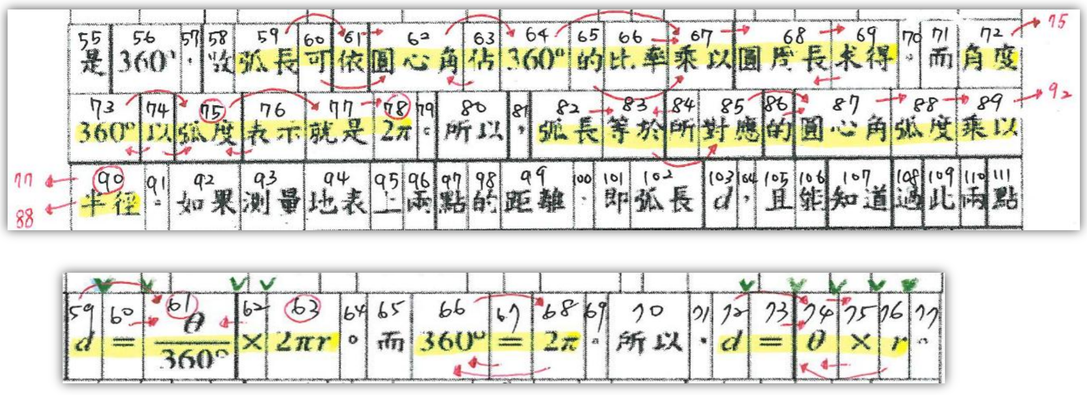

Figure 2. The different scan path of verbal (upper) and equation (lower)

Discussion

- Reading materials of this study based on geometric knowledge before 9th grade. For university participants, there was no difference between two versions in difficult rating, reading comprehension, and response time.
- However, the equation version had similar total viewing duration with the verbal version, even key area of the equation version was smaller and had less visual input. Besides, percentage of reading graph in the equation version was higher than the verbal version.
- Eye movements showed readers consumed more time on processing equation representation, and need to refer to graphs more, although the readers of two versions have similar behavior performance.
- This finding indicates that the equation version need different reading skill than the text version.

References

Ö sterholm, M. (2006). Characterizing reading comprehension of mathematical texts. *Educational Studies in Mathematics, 63*(3), 325-346.