Symbol Training in Past 40 Years

Annie W.Y. Ng and Alan H.S. Chan

***Abstract*—Previous studies found that training significantly improved the comprehensibility of graphical symbols. The aim of this paper is to present a comprehensive review of symbol training in past 40 years. Three symbol-training methods (i.e. paired-associate learning, recognition training, recall training) that were commonly used by ergonomists or industrial designers are identified in this paper. Relationships between training methods and symbol comprehension are summarized. Experimental design and analysis for symbol-training studies are also described. This review would be helpful in formulating research plans and methodology for conducting other symbol-training studies.**

***Index Terms*—graphical symbol, symbol-training method, paired-associate learning, recognition training, recall training**

I. Introduction

The term signs, icons, symbols, pictograms, pictographs, and glyphs often appear and appear to be interchangeably in the literature for depicting physical objects, concepts, or functions. Even though users may guess what an icon represents at the very first time, training could improve the process of understanding the meaning of an icon [1]. Blum and Naylor [2] defined training as 'a process that develops and improves skills related to performance'. Bailey [3] identified training as 'the systematic acquisition of skills, knowledge, and attitudes that will lead to an acceptable level of performance on a specific task in a given context'. The extent to which training brings desired or appropriate outcomes is called training effectiveness [4].

Prior researches revealed that training significantly improved the comprehension of the meaning of symbolic traffic signs [5], occupational safety symbols [6], industrial-safety and pharmaceutical symbols [7], service symbols [8], warning symbols in products [9], and hazardous material symbols [10]. In this paper, a comprehensive review on symbol-training in past 40 years is given and some current symbol-training methods are identified. Relationships between training methods and symbol comprehension are also presented. Experimental design and statistical analysis for symbol-training studies are also summarized. This review would be helpful in providing useful background information for formulating research plans and methodology for conducting further symbol-training studies.

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II. Symbol-Training Methods

Table 1 presents a summary of studies related to symbol training in past 40 years. Three symbol-training methods have been commonly used by ergonomists or industrial designers. The first method is called paired-associate learning. With this method, the learning is done in pairs of a symbol and its meaning so that one member of the pair evokes recall of the other [5], [11] - [13]. Other than the option of providing a short phrase, other means such as a mnemonic cue [14], an explanatory statement explaining the nature of the concept or hazard [7], or a short paragraph describing an accident that results from failure to comply with the symbol [9] was also used.

The second method is called recognition training. Recognition is the ability 'to identify something or someone that has been seen, heard, etc. before' [15]. With this method of training, subjects were first informed of the meanings of all symbols. They then were given the meaning of a symbol and asked to choose the most appropriate symbol among the given selections in a trial. Feedback on the response accuracy was provided immediately [8] [10] [16].

The third method is called recall training. Recall means 'bring something or someone back into the mind or recollect' [15]. An earlier study of Brown [17] stated that the examination of distracters in recognition may produce some sorts of interference and Sternberg [18] indicated that recall tasks elicited a deeper level of learning than recognition tasks. In the recall training method, subjects were first notified about the meaning of the testing symbols and then orally recalled the meaning of every randomly selected symbol. Feedback on the accuracy of responses was given [8] [10] [16].

III. Effects of Training Methods on Symbol Comprehension

There does not appear to have been any research comparing the effectiveness of different symbol-training methods. However, there are a few studies about the relationship between paired-associate learning and symbol comprehension [5] [7] [9] [14]. A summary of these studies is given in the following paragraphs.

Griffith and Actkinson [14] assessed the influence of training on 128 international road signs comprehension for drivers in the United States Army armour. Three training conditions viz. sign only, sign elaboration, and standard lecture were employed in their study. In the sign only condition, the signs were presented individually for 10

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Table 1 A summary of studies related to symbol training

Studies	Purpose	Subjects	Symbols	Training method
Walker *et al*. [11]	investigated the hypothesis that symbolic road signs could be more accurately recognized than verbal road signs	81 students	3 symbolic and 3 verbal traffic signs	Subjects studied the signs and their meanings for five minutes printed on sheets of paper
Griffith and Actkinson [14]	studied the effects of training on the interpretability of road signs	Drivers in the US Army armour	128 international road signs	Three conditions were used as follows: (i) Sign only: the signs were presented individually for 10 seconds each while the instructor read aloud the name of the sign twice. (ii) Sign elaboration: the signs were presented individually for 10 seconds each while the instructor provided the name of the sign and mnemonic cue orally. (iii) Standard lecture: a series of lessons supplemented with training aids.
Allen *et al*. [5]	assessed the effects of age and training on traffic sign recognition	Drivers	72 symbolic traffic signs used in the United States	Three conditions were used as follows: (i) Received an educational pamphlet explaining the meaning and nature of the signs. (ii) Received a review of each sign with an educational plaque below it in the driving stimulator. (iii) Both (i) and (ii).
Cairney and Sless [6]	evaluated the performance on symbol identification	144 students from adult education	19 occupational safety symbols	Subjects were required to identify the meaning of a randomly selected symbol within 30 seconds. The experimenter provided feedback on the accuracy of their responses.
Wogalter *et al*. [7]	assessed the effect of training on the comprehension and retention of symbols over time	60 university students	20 industrial-safety and 20 pharmaceutical symbols	Two conditions were used as follows: (i) While subjects viewed each symbol along with a verbal label, the experimenter read aloud the label. (ii) While subjects viewed each symbol along with a verbal label and an explanatory statement, the experimenter read aloud the label and statement.
Ramakrisnan *et al*. [8]	evaluated the effectiveness of symbol coding techniques	28 airway facilities field personnel	21 Federal Aviation Administration facilities and service symbols	The method contained three steps: (i) Subjects were shown the correct symbol for each examined facility. (ii) Recognition training For each trial, subjects saw the name of a facility and were asked to choose the corresponding symbol among a set of symbols until the correct symbol was identified. The name and the symbol remained on the screen for 3 seconds in order to help subjects learn the symbol. (iii) Recall training For each trial, subjects were required to orally recall the meaning of a symbol. The correct meaning was provided immediately after each response.
Wang and Chen [12]	investigated the effects of symbol, gender, and training on symbol comprehension	60 university students	12 hazard symbols	The experimenter told the subjects the meaning of the symbols.
Wang *et al*. [16]	studied the effects of prohibitive traffic signs design on users' subjective preference and visual performance	40 university students	9 symbolic and 1 verbal Taiwan traffic signs	The method contained three steps: (i) The experimenter told the subjects the meaning of the signs through the use of a traffic sign booklet. (ii) Recognition training For every trial, subjects saw the meaning of a randomly selected sign and were asked to choose the corresponding sign from the booklet until the correct sign was identified. The experimenter repeated the answer once in order to help subjects learn the sign. (iii) Recall training For each trial, subjects were required to orally recall the meaning of a randomly selected sign until the correct meaning was recalled. The experimenter repeated the answer once in order to help subjects learn the sign.
Chen and Wang [13]	explored the effects of symbol, education level, and gender on conceptual compatibility	48 participants	12 hazard symbols	The experimenter told the subjects the meaning of the symbols.

Table 1 A summary of studies related to symbol training (continued from the previous page)

Studies	Purpose	Subjects	Symbols	Training method
Lesch [9]	studied age related differences and impact of training on comprehension and memory for warning symbols	92 participants	41 warning symbols used for labelling hazards associated with products	Three conditions were used as follows: (i) Verbal label: subjects viewed each symbol along with a verbal label describing the meaning of the symbol. (ii) Explanatory statement: subjects viewed each symbol with a verbal label and a brief statement explaining the nature of the hazard. (iii) Accident scenario: subjects viewed each symbol with a verbal label and a short paragraph describing an accident that resulted from failure to comply with the symbol.
Wang and Chi [10]	investigated the effects of symbol, educational specialization, and training on symbol comprehension	60 university graduates	12 hazardous material symbols	The method contained three steps: (i) The experimenter told the subjects the meaning of the symbols through the use of a hazard symbol label booklet. (ii) Recognition training For every trial, subjects saw the meaning of a randomly selected symbol and were asked to choose the corresponding symbol from the booklet. The experimenter provided feedback on the accuracy of their responses. (iii) Recall training For each trial, subjects were required to orally recall the meaning of a randomly selected symbol. The correct meaning was provided for any incorrect responses made.

seconds each while the instructor read aloud the name of the sign twice. In the sign elaboration condition, the signs were presented individually for 10 seconds each while the instructor provided the name of the sign and mnemonic cue orally. Standard lecture was a series of lessons supplemented with training aids. Performance on sign comprehension was shown to improve after training. But there were no statistically significant differences among the training conditions.

Allen *et al*. [5] investigated the effect of training on the understanding and retention of 72 symbolic traffic signs contained in the United States Manual on Uniform Traffic Control Devices for drivers. One group of drivers received an educational pamphlet explaining the meaning and the nature of the signs, one group received a review of each sign with an educational plaque below it in the driving stimulator, and one group received a combination of both. The results revealed that all the three training conditions increased comprehension and memory for the meaning of traffic signs. However, the differences amongst training conditions were insignificant.

Wogalter *et al*. [7] examined the influence of training on the understanding and memory of 40 industrial-safety and pharmaceutical symbols. Two paired-associate learning conditions were tested: verbal label condition and verbal label with explanatory statement condition. Thirty participants viewed each symbol along with a verbal label (i.e. for describing the meaning of the symbol) while the experimenter read aloud the label. Another 30 participants viewed each symbol along with a verbal label and an explanatory statement (i.e. for describing the nature of the concept on hazard), while the experimenter read aloud the label and statement. The results demonstrated that both conditions improved comprehension and memory for the meaning of test symbols. Surprisingly, comprehension and memory was no better when an additional explanatory statement was provided than when a verbal label alone. This may be attributed to the fact that (i) subjects were not able to encode the explanatory statements satisfactorily, (ii) the retention measure was not sensitive enough to evaluate the consequence of the explanatory statements, (iii) the verbal label alone evoked retention to a near-ceiling effect, and (iv) the explanatory statements failed to provide additional memory codes other than those provided by the verbal labels.

Lesch [9] evaluated the effect of training on the comprehension and memory of 41 warning symbols used for labelling hazards associated with products. In addition to verbal label and explanatory statement conditions, an accident scenario condition was included as well. In the verbal label condition, subjects viewed each symbol along with a verbal label describing the meaning of the symbol. In the explanatory statement condition, subjects viewed each symbol with a verbal label and a brief statement explaining the nature of the hazard. In the accident scenario condition, subjects viewed each symbol with a verbal label and a short paragraph describing an accident that resulted from failure to comply with the symbol. It was found that the three training conditions significantly enhanced the understanding and retention of the meaning of warning symbols. The verbal label produced the best performance, followed by the explanatory statement, and then the accident scenario. There were two reasons for explaining the failure of the accident scenario condition to provide additional benefit relative to the explanatory statement and verbal label conditions: (i) the length of the scenarios and the large number of symbols trained might have over-loaded the memory and (ii) participants might not process the accident scenario sufficiently.

IV. EXPERIMENTAL DESIGN AND ANALYSIS FOR SYMBOL-TRAINING STUDIES

Pretest-posttest designs are widely used in symbol-training research, primarily for the purpose of measuring the effectiveness of different training conditions [5] [7] [9] [10]

[12]. Subjects were measured before and immediately after training in pretest and posttet, respectively. For determining whether training effects maintained over time, another posttest was held one week [5] or one month [10] following the immediate posttest. To prevent subjects from retaining the meaning of test symbols in short-term memory through subvocal rehearsal, intervening task such as letter search task and demographic questionnaire [7], playing poker [10], and puzzle game [12] was performed immediately after training.

Posttest score, difference score, and percentage change are three common indicators of training effectiveness. Difference score is the change in score between posttest and pretest. Percentage change is the ratio of difference score to pretest score. It is not recommended for use in the analysis of pretest-posttest design [19] [20]. This is because firstly, the distribution of percentage change is usually non-normal and thus violates the assumptions of most parametric statistical tests. Secondly, percentage change would create a bias and overemphasize the performance improvement of the group with poorer baseline scores. Nevertheless, some recent studies have used this statistic in pretest-posttest design analysis [21] [22]. Newby [23] recommended gain ratio, which compares the actual improvement and the theoretical maximum room of improvement, for measuring the amount of learning achieved by a trainee during a training activity. Gain ratio was earlier used by Hovland *et al*. [24] and some recent education studies [25]-[29]. However, it has not been used in symbol-training research.

Three methods are recommended for studying data collected from pretest-posttest comparison group design: (i) posttest score approach, (ii) analysis of covariance approach, and (iii) difference score approach [30] [31]. Assuming that there are three treatment groups and one control group in a pretest-posttest design, subjects are randomly assigned to the groups prior to pretest, and each group is measured before and after training. With the first approach, an analysis of variance is performed using posttest score as the dependent variable and treatment condition as the independent variable. With the second approach, an analysis of covariance is conducted using pretest score as the covariate, posttest score as the dependent variable, and treatment condition as the independent variable. In the third approach, an analysis of variance is performed using difference score as the dependent variable and treatment condition as the independent variable. When the data to be analyzed in the pretest-posttest design are not normally distributed, nonparametric analyses should be undertaken. Posttest score approach is less powerful than the other two approaches as pretest scores are ignored during data analysis [31]. Girden [32] specified that when the regression coefficient of posttest score on pretest score equals one, difference score approach and analysis of covariance (ANCOVA) approach will produce the same F ratio, with difference score analysis being slightly more powerful due to the lost degrees of freedom with ANCOVA. When the regression coefficient is less than one, the error term will be smaller in ANCOVA, resulting in a more powerful test.

It was noted that performance may change from pretest to posttest without treatment through maturation, history, regression revisited, mortality, instrumentation, and testing [33]. *Maturation* denotes the natural physiological changes from pretest to posttest within the trainee such as fatigue, hunger, and growth. *History* specifies events other than the treatment that have occurred between pretest and posttest. For example, there may be an increase in room temperature. *Regression revisited* refers to the situation where participants are chosen on the basis of their extreme pretest scores. Regardless of whether there is a treatment, subjects whose scores are high (low) on the first assessment will probably show a decrease (an increase) in score when they are measured a second time. *Mortality* indicates a phenomenon occurring when fewer participants at posttest than pretest were measured. *Instrumentation* denotes that the measuring instrument used for posttest is different from the one used during pretest. *Testing* refers to the situation where pretest has a positive change on posttest performance. As performance may change from pretest to posttest without treatment, the above six factors should be considered in the design of pretest-posttest experiments for symbol-training studies.

V. Conclusion

In the paragraphs above, a comprehensive review on symbol training in past 40 years was presented. Three commonly used symbol-training methods, viz., paired-associate learning, recall training, and recognition training were identified. The effects of training methods on symbol comprehension were given. The experimental design and statistical analysis for symbol-training research were also described. This review would be helpful for the design of more user-friendly symbol training programs for use in industry.

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