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Perceptual learning: An analysis based on selective attention measurements

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An experiment was carried out to assess the relative merits of the differentiation and association theories of perceptual learning. Two Hebrew and two Roman characters were used to form stimuli describable by three orthogonal dimensions: form, system, and name. Two groups of subjects, who differed in their ability to read Hebrew, did a series of card sorting tasks. The results indicated that the subjects who could read Hebrew were able to use the name dimension in a classification task, whereas the non-Hebrew readers were not. This finding shows that long-term associative learning can facilitate perceptual classification.

To explain the role of learning in perception, J. J. Gibson and E. J. Gibson (1955) argued that there are essentially two theories of perceptual learning. According to the *association theory*, perception becomes enhanced by memory associations acquired during learning. As more memories are accumulated, a constant sensory input gives rise to more diverse experiences. In contrast, the *differentiation theory* states that, as a result of learning, perception corresponds more closely to the stimulation in the environment. The perceiver makes finer discriminations because he/she has learned to respond to variables of stimulation that were not previously responded to in a given sensory input.

It is useful to consider the evidence that has been used to support the differentiation theory. J. J. Gibson and E. J. Gibson (1955) assessed perceptual learning by presenting subjects with a set of unfamiliar forms and measuring the number of trials required to learn to discriminate a critical form from the others. Their results showed that at first, subjects were unable to distinguish the critical form from an entire class of forms, but, as a result of learning, their responses to the various stimuli became more accurate.

Although the differentiation theory has been supported by subsequent experiments (e.g., E. J. Gibson, 1963, p. 173; Pick, 1965), it has certain conceptual limitations. For example, the learning it describes occurs during a single experimental session. Research based on a single session does not describe changes in perception that are the result of years of training. In addition, Postman (1955) argued that the differentiation theory fails to describe the processes that mediate the increased differentiation. He also noted that this theory is not appropriate for analyzing how symbolic stimuli are perceived.

To evaluate these opposing ideas, we will describe an information-processing experiment that we designed to study the role of learning in perception.

Garner, Podgorny, and Frasca (1982) recently carried out a set of experiments to determine whether a stimulus name functions in the same way that physical attributes do. Although their research was not directly concerned with perceptual learning, we used their findings to study this problem in terms of the selective attention paradigm that has been used to study the interaction of various kinds of stimulus attributes (e.g., Garner, 1978; Garner & Felfoldy, 1970; Pomerantz & Garner, 1973). To explain why their research is relevant, we will mention two aspects of their work.

The stimulus set used by Garner et al. (1982) is useful for studying perceptual learning because it is described by physical and cognitive stimulus dimensions. A physical dimension is one on which the physical properties of the stimuli are adequate for carrying out a task, whereas a cognitive dimension is one on which the physical properties are insufficient to accomplish a task, so that the subject has to make his judgment using a learned association. In addition, Garner et al. argued that a cognitive dimension can provide recoding or generation of physical images, whereas a physical dimension cannot.

In the present experiment, we used card-sorting tasks to study how learning that has taken place over a number of years can affect perception. To examine the differences between physical and cognitive stimulus dimensions, Garner et al. (1982) used the Roman and Arabic characters *VI*, *6*, *X*, and *10*, which differ on the attributes of length, system, and name. To adapt their work to the study of perceptual learning, we selected characters from the Roman and Hebrew alphabets, so that the name dimen-

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sion would be more familiar to one group of subjects than to the other. We assumed that subjects who could read Hebrew would be able to use the cognitive dimension as a processing mechanism, whereas the subjects who had no experience with Hebrew would not.

METHOD

Subjects

The subjects were 22 Yale undergraduates and graduate students. Eleven had no knowledge of Hebrew, and 11 could read Hebrew aloud at a minimum rate of 80 words per minute.

Stimulus Construction

The stimuli were two letters each from the Roman and Hebrew alphabets, as shown in Figure 1. The upper left letter is *gimel* and the upper right letter is *mem*. These Hebrew letters have a name equivalence with the Roman letters *G* and *M*. Thus, for purposes of exposition, in the text *gimel* will be notated as *G'*, and *mem* will be notated as *M'*.

These letters can be described by three orthogonal dimensions that vary along a physical-to-cognitive continuum: form (curved or straight), system (Roman or Hebrew) and name (/m/ or /g/). Form, defined along the horizontal axis, is a physical dimension, because the shape of the letters is sufficient to identify the two pairs of characters defined by this dimension. System, defined along the vertical axis, is intermediate between the physical and cognitive dimensions, because even though these two pairs of letters are arbitrarily defined as belonging to different alphabets, we can correctly classify these letters without knowing Hebrew. Name, defined by the two pairs of letters formed by the diagonals, is a cognitive dimension, because we must know the phonetic labels of these letters to classify the letters by this dimension.

The stimuli were typed on 6.3×8.9 cm white cards; one letter was centered on each card. The upper right-hand corner of each card was cut off to maintain the proper orientation of the cards during the experiment. The cards were also covered with thin plastic to facilitate sorting. The Hebrew characters were typed with an IBM Aviv-10 typing element and the Roman characters were typed with an IBM Artisan-96 typing element. These type fonts were selected because their characters were deemed to be the most similar in terms of size, width, darkness, and overall style. Each character was approximately 3 mm tall, so that during the experiment they subtended a visual angle of 1° to 2°.

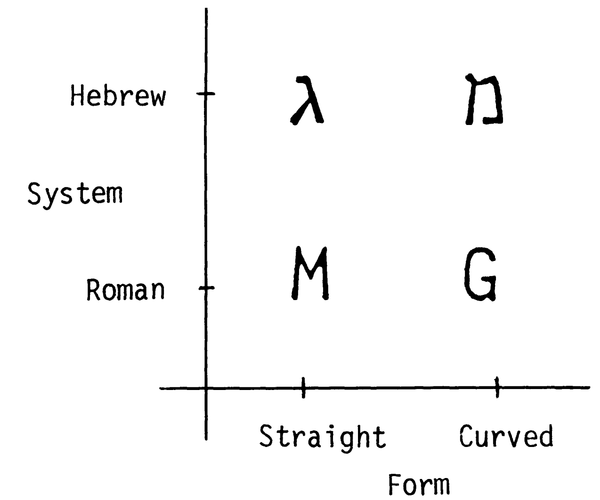

Figure 1. Four stimuli generated from three orthogonal dimensions: form, system, and name. In the text, the Roman letters are referred to as *G* and *M*, and the Hebrew letters which have these names are referred to as *G'* and *M'*, top left and right, respectively.

Table 1
Mean Sorting Times for Tasks Based on the Stimuli in Figure 1

		Group		
		Non-Hebrew	Hebrew	Mean
		Discrimination Task		
Form	*G'/M'*	15.8	16.1	15.8
	G/M	15.5	15.6	
System	*M'/G*	15.6	15.7	15.7
	M/G'	15.7	15.6	
Name	*G/G'*	15.5	15.6	15.8
	M/M'	16.0	16.0	
Mean		15.7	15.8	
		Focusing Task		
	G'/M'MG	16.0	16.0	16.0
	M'/G'MG	16.6	16.4	16.5
	M/G'M'G	16.1	16.4	16.3
	G/G'M'M	15.5	16.3	15.9
Mean		16.1	16.3	
		Classification Task		
Form	*G'M/M'G*	21.8	24.7	23.3
System	*G'M'/GM*	16.9	17.0	17.0
Name	*G'G/M'M*	19.7	17.2	18.5
Mean		19.5	19.6	

Note—Entries are mean times in seconds needed to sort a deck of 36 cards into two piles.

Tasks

Thirteen different tasks were used in the experiment. Each task required the subject to sort a deck of 36 stimulus cards into two piles based on a prespecified stimulus grouping. The tasks were of three general types; they are diagramed in Table 1. The discrimination and focusing tasks can be thought of as control tasks, whereas the classification tasks provide a way to directly address the issues that were raised about perceptual learning. (See Garner, 1978, for a more detailed description of these tasks.)

Discrimination tasks. In these tasks, each deck of cards had only two of the four stimuli. The decks contained 18 stimuli of each type and the subjects were required to sort the two kinds of stimuli into different piles. There were six different discrimination tasks.

Focusing tasks. All four stimuli were used to make up the decks for these tasks. The subjects were required to place one of the stimuli in one pile and the other three stimuli in the other pile. Each pile had 18 focused stimuli and 6 each of the other 3 stimuli. There were four different focusing tasks.

Classification tasks. Once again, all four stimuli were used for these tasks, but the four stimuli were placed into two classes of two stimuli each. Each deck had nine of each stimulus.

In terms of the three dimensions used in generating these stimuli, we can define three classification tasks, each of which is a selective attention task. For the dimensions of form and system, there should be no difficulty in their being perceived as dimensions by either group of subjects. The name dimension could be expected to serve as a cognitive dimension for the Hebrew group; for the non-Hebrew group, however, it should not serve as a dimension, in which case this classification task is more accurately described as a biconditional task in which both form and system have to be processed. Such tasks are usually more difficult than classification tasks that allow selective attention.

Procedure

On each trial the subject was given a deck of cards, along with two or four guide cards to indicate the particular classification that was required. To ensure that the subjects who did not know Hebrew would be clear about the correct names of the Hebrew letters, the experimenter also mentioned the names of the stimuli involved in each trial. The subjects were then instructed to sort the decks of cards into two piles as quickly and accurately as possible. After each sort, the time was recorded to the nearest 10th of a second and the number of errors was noted.

The order of the tasks was counterbalanced across subjects, each subject having one particular order. These orders were pseudorandom, with the constraint that each of the three types of task occurred equally often at all points in the order. Each subject was run on all tasks once in the assigned order, once in the reverse order, and again in the original order. Thus, each subject was run on three blocks of 13 trials. Approximately 1 h was required for each subject to complete the experiment.

RESULTS

The results are shown in Table 1, grouped according to the three types of tasks. All sorting times are averaged over the last two blocks of trials. The first block was considered practice, and no data from this set of trials were analyzed. Errors were not analyzed because the majority of trials were errorless. Several analyses of variance were carried out, based on a design in which subjects were nested in groups and crossed by tasks. Nonparametric tests and t tests were used to complement these analyses.

Discrimination Tasks

The discrimination tasks were not equally difficult, as shown by a significant task main effect [$F(5,100) = 3.39$, $p < .01$]. However, an examination of the means shows that the differences are very small and the averages of the pairs of controls for the three different dimensions are virtually identical. Thus, these differences are idiosyncratic. Because we are primarily concerned with the effect of learning on perception, the important result is that the two groups of subjects did not differ on these tasks: the group main effect and the task × group interaction both fail to reach significance [$F(1,20) = .015$ and $F(5,100) = .442$, respectively]. These tasks therefore provide baseline measurements and show that the familiarity of the name dimension does not differentially influence the discriminability of the dimensions.

Focusing Tasks

The focusing tasks were not equally difficult, as shown by a significant task main effect [$F(3,60) = 6.02$, $p < .01$]. However, as in the discrimination tasks, these differences are small. Although the group main effect is not significant [$F(1,20) = .115$], there is a significant task × group interaction [$F(3,60) = 3.14$, $p < .05$]. If the groups were to differ in their ability to use a focusing strategy, the most reasonable outcome would be that the difference would in some way involve the Hebrew characters. But a comparison of the means suggests that the groups differed in their ability to use *G* as a focused stimulus. The interaction is therefore due to an anomalous result in which this time is the same as for any of the discrimination tasks. We have no explanation for this finding. Although the focusing means are larger than the means for the discrimination tasks, there is evidence that all subjects were able to use a focusing strategy.[1]

Classification Tasks

The groups did not differ in their overall performance on these tasks [$F(1,20) = .028$], but both the task main effect and the task × group interaction are significant [$F(2,40) = 29.93$, $p < .01$, and $F(2,40) = 4.95$, $p < .05$, respectively]. Because the classification tasks are critical to an understanding of the effect of learning on perception, it is worthwhile to examine each one separately.

Form. Although it appears that the groups differed on this task, because of high variability between subjects, this difference is not significant [$t(20) = 1.50$]. Also, sign tests showed that all subjects found this task more difficult than the corresponding discrimination tasks. Thus, regardless of their knowledge of Hebrew, subjects could not selectively attend to the dimension of form. This failure of selective attention is probably due to the fact that our stimuli were letters from different alphabets. Because we were attempting to choose four letters that differed on three dimensions, we were unable to unequivocally satisfy the form distinction.

System. Once again, the two groups did not differ on this task [$t(20) = .166$], and sign tests showed that both groups found this task more difficult than the corresponding discrimination tasks. However, the means for this classification task are substantially lower than the means for classification on the basis of form. This comparison therefore suggests that, to a considerable degree, subjects could selectively attend to the dimension of system, regardless of their knowledge of Hebrew.

Name. In contrast to the other classification tasks, the groups differed on this task [$t(20) = 6.28, p < .01$]. This finding provides evidence for a differential failure of selective attention. Although sign tests showed that both groups found this task more difficult than the corresponding discrimination tasks, the between-groups difference indicates that the Hebrew subjects could selectively attend to the name dimension to a greater extent than could the non-Hebrew subjects.

DISCUSSION

The discrimination and focusing tasks showed that learning does not affect perception with regard to discriminating physical and cognitive stimulus dimensions or processing individual stimuli within a set. These null results imply that perceptual learning cannot be described completely by basic stimulus familiarity effects (e.g., Ambler & Proctor, 1976; Egeth & Blecker, 1971; Posner & Mitchell, 1967). In contrast, the classification tasks showed that, as a result of learning, the Hebrew subjects had acquired the ability to use the name dimension as a processing mechanism. For these subjects, the task requiring classification by name was carried out like a selective attention task, in which subjects filter out irrelevant variations in form and system. The non-Hebrew subjects, however, could not use the name dimension, so they performed this task as a biconditional classification of form and system.

These results suggest that a name is similar to a stimulus configuration. When stimulus dimensions interact to form configurations, the dimensions used to generate the stimuli are irrelevant in determining how the stimuli are processed (Pomerantz & Garner, 1973; Pomerantz & Schwaitzberg, 1975). In the present experiment, although we defined a set of stimuli using three dimensions, only the Hebrew readers could use the name dimension in an information-processing task. Thus, as a result of learning a stimulus name, subjects acquired the ability to carry out a classification task in a way that was not directly related to the discriminability of the attributes used to define the stimuli. We can, therefore, distinguish between a name and a configuration because a name acquires its processing function as a result of learning, whereas a configuration already has its processing function because it is an inherent stimulus property (Garner, 1978).

This experiment suggests that the differentiation theory may not provide a complete description of perceptual learning. J. J. Gibson and E. J. Gibson (1955) argued against the idea that memories acquired during learning can influence perception. They emphasized that the stimulus contains a great deal of "higher order" information and that, as a result of learning, subjects acquire the ability to discriminate more of this information. We have demonstrated that a learned stimulus name can facilitate perceptual classification. Thus, associations have at least some role in perceptual learning.

Although associations can influence perception, it is important to note that Postman's (1955) theory identifies perceptual learning as a change in stimulus-response relationships. Postman stated that the organism has learned to perceive the meaning of a stimulus when it has learned to make the appropriate response. In fact, this response-based analysis is also inherent in the differentiation theory. To describe what has changed as a result of learning, J. J. Gibson and E. J. Gibson (1955) argued that there is an increase in the specificity of the discriminating response so that the subject can respond to more of the information in the stimulus. Following Garner, Hake, and Eriksen (1956), we would like to emphasize that the response is not, in itself, important in understanding perceptual learning. Rather, the response allows us to study how the percept has changed as a result of learning.

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NOTE

1. The results from the focusing tasks also provide a way to dismiss a potential problem with this stimulus set. The Hebrew character *G′* closely resembles the Greek character lambda; thus, it is possible that the subjects who did not know Hebrew were in some way more familiar with this stimulus than with the other Hebrew letter. An analysis of variance on the two focusing tasks that used Hebrew characters as the focused stimuli shows that the group × task interaction is not significant. Thus, in response to the claim that the two Hebrew characters may not have been equally unfamiliar, it appears that subjects who did not know Hebrew were not able to process these characters differentially relative to the subjects who knew Hebrew.

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