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論　文

Components in "Same"-"Different" Judgments as an Interface between Perception and Higher Cognition (3)

知覚とより高次の認知をつなぐインターフェイスとしての同異判断（3）

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Saito(1996) proposed a theory of "same"-"different" judgment reaction time. The purposes of the theory were as follows: (1) to explain matching phenomena; (2) to provide links between the phenomena and our knowledge regarding perception and cognition; and (3) to demonstrate a processing principle: The principle states that in pattern matching judgments, reaction times and error rates do not depend on quantitative judgment-criteria settings but on differing rules across resolution levels of analysis. Saito (1997) constructed a mathematical model of a subset of the theory in order to analyze some important characteristics of the theory. The present research aims at discussions on applications of the theory to matching tasks and to relevant phenomena.

In the theory, a descriptor has four subprocesses; Level 1 outputs very global descriptions of visual stimuli, and Level 4 describes very fine details of them. These levels are assumed based on Palmer's investigations (Palmer, 1975; 1977; 1985). Each of the subprocesses produces multiple descriptions of a stimulus; every description produced by a subprocess is identical-resolution ones, but they are based on different viewpoints; and a different set of symbolic units is used for producing each different description. That is, each individual subprocess analyzing a stimulus at a level of resolution produces a set of multiple descriptions which are based on various viewpoints. In such subprocesses, "same"-"different" judgment results from a search for a correspondence between descriptions of a stimulus pair: Each of four different-resolution subprocesses of the descriptor produces two sets of descriptions, one set for each of two stimuli. When "same"-"different" judgment is needed, each subprocess searches across the two sets. Each individual subprocess then cries "same !" when it finds a correspondence between descriptions. All descriptions produced by a given subprocess are the results of identical-resolution analyses, and any-viewpoint match is acceptable as that-level "sameness" (though different viewpoint descriptions help identification by a categorizer); the categorizer hence selects a level of "sameness", according to a specific purpose. This build-in strategy is based on Krueger's theorem (see Krueger, 1978; Saito,1996). The criterion value of judgment is assumed to be constant in most predictions.

Basic assumptions about different levels of

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subprocesses are as follows (for details, see Saito, 1996): (1) Level 1 describes the categorical size of stimulus and global linearity (or curvilinearity). This subprocess also controls a size scaling mechanism. (2) Descriptions produced by Level 2 represent the outline of stimulus (i.e., 'boxness,' 'circleness,' 'triangleness,' and so forth) as well as other global features (un-filled figure, filled figure, and so forth). (3) Level 3 delineates stimulus structure, but this can specify neither slight skew nor tiny ornaments of letters or objects. (4) Level 4 describes enough fine details to specify a clear visual image.

When many letters are presented together in the same visual field, two subprocesses, Level 1 and Level 2, can not discriminate proximal letters, because their resolution levels of analysis are low. Consequently, they integrate the letters as a whole. On the other hand, Level 3 describes four letters as a group (see Saito, 1996;1997), and Level 4 describes items in a one-by-one manner. However, the value of the grouping limit in Level 3 increases with high familiarity (e.g., spelling pattern: Spoehr and Smith, 1975), as mentioned below.

Strategies Employed by the *Categorizer*: Determinants of the Resolution level.

In the theory, we should consider determination strategies for the resolution level when experimental manipulations include more-than-four letter-string lengths, very complex stimuli, too easily-discriminable stimuli, and so forth. In this paper, the level selection strategies employed by the categorizer are discussed. Then experiments are classified into six types.

The main determinants of resolution level are the heterogeneity of stimulus difference, letter-string length, and stimulus complexity. The effect of familiarity will be discussed later. In this section, only experiments using unfamiliar (random) letter strings or patterns are discussed. In those experiments, each letter within the strings or each element (triangle, circle, or so forth) of the patterns is familiar.

For "same" response, the categorizer must select either Level 3 or Level 4 responses when the heterogeneity is insufficiently low within an experimental block. That is, neither Level 1 nor Level 2 can describe fine internal stimulus structure; hence, their "sameness" may not be equal to the "sameness" defined by the experimenter in some trials.

On the other hand, when "different" pairs are defined as not-"same" ones, stimulus sets may contain various "differences." This implies that even lower-resolution-level "differences" other than an adequate "same" level are acceptable. When any lower subprocess cries "different !", the categorizer can immediately release an overt response. This response is mediated by the lowest level subprocess among the subprocesses which can find "difference," because lower resolution-level subprocesses stabilize quicker. If the stimulus set used is highly heterogeneous, the mean "different" reaction time value will be an expression of various-level-"difference" detection latencies. To sum up, the strategy of the categorizer requires that a level of "sameness" should be selected in an individual task, but any lower level "difference" is acceptable. That is, only "difference" levels higher than a selected "same" level are unacceptable. Note that in each subprocess (each level), the decision ruling across seven viewpoints cancels out the effect of spurious mismatch produced by the internal noise (see Saito, 1996; 1997). Simply, the categorizer has only to select a level of resolution based on the properties of any individual-level subprocess.

Table 1 summarizes the relations between main experimental variables and types of experiments.

Table 1
Classification of matching experiments.

the heterogeneity of difference is either intermediate or high			the heterogeneity of difference is low enough		
string length			string length		
L < 5+		L >= 5	L < 5		L >= 5
letter++ or simple figure	very complex figure		letter or simple figure	very complex figure	
Case A	Case B	Case C	Case D	Case E	Case F

+ when either extremely simple stimuli (such as digits of 1 or 0) or familiar ones are used, the number is more than 4.
++ complexity as Kanji (ideogram, one of the character set used in Japanese) or lesser than that.

(1) Case A refers to the type of experiment in which heterogeneity is either intermediate or high, the length of the letter string (or simple pattern string) is less than five, and the degree of string-element complexity is like letters, at the maximum, as complex as ancient Chinese characters, or Kanji used in Japan. In such an experiment, each description has fairly good compactness because of both small complexity and short string length. Then, the categorizer accepts "sameness" at Level 3 to trigger "same" response. In this case, the heterogeneity difference is not low enough, and therefore several "different" responses are an expression of lower-level "differences." Consequently, the "fast-same" disparity will be smaller than that in Case D (in this case, the heterogeneity is small enough; see the section of Case D).

(2) Case B refers to the type of experiment in which stimuli are very complex while other factors are the same as in Case A. Level 3 cannot describe the complex stimuli in detail. In such an experiment, only Level-4 "sameness" is adequate for that defined by experimenter. On the other hand, because of heterogeneity, some "different" responses will be an expression of lower-resolution-level "differences."

The "fast-same" phenomenon will be either small or negative. "Same" responses are always an expression of "sameness" at Level 4 which is the slowest subprocess. Mean "same" reaction time is hence greater than that in Case A. On the other hand, the probability that the categorizer accepts lower level "differences" is not small enough, because of the heterogeneity of stimulus difference. Hence, the probability of slower "same" responses rather than "different" responses will not be small. This prediction may be difficult to test directly because the manipulation of stimulus complexity on a large scale simultaneously varies discriminability for "different" pairs. According to the present theory, stimulus complexity in some degree increases reaction times while high discriminability decreases it. On the one hand, both overly-large complexity and high discriminability decrease the "fast-same" disparity. Therefore some experimental results were rather confused. This could be attributed to the covariation of dissimilarity and complexity.

Silverman(1974) employed strings of very simple shapes as stimuli; the strings differed in outline shape. The categorizer then selected Level-2 "sameness." In his experiment, the "fast-same" phenomenon was found through string lengths under a high "discriminability" condition. On the other hand, under a low "discriminability" condition, the phenomenon was found only for a string length of 1. For string lengths of more than one, "different" responses were faster than "same" ones. Using the term of discriminability (as he used it), these results were inconsistent with both the results reported by Silverman and Goldberg(1975) and by Taylor(1976). They found the inverse relation: high discriminability suppressed the "fast-same" phenomenon.

This contradiction can be attributed to Silverman's(1974) stimulus manipulation. He manipulated "discriminability," using individual element shapes of differing complexity. Therefore complexity inhibited the "fast-same" phenomenon. It should be noted that his complexity manipulation decreased outline-shape differences between stimuli, and thus Level-2 "sameness" became unreliable. That is, many "different" pairs were judged as "same." On the other hand, some parts of the stimuli had a varying black/white ratio (see his Figure 1). Hence, when, by chance, the internal noise level was not high, Level 2 could detect the "difference." Note that the categorizer does not know the noise level, and that it ought not accept Level-2 "sameness." As mentioned above, a "sameness" level must be selected, but any lower-level "difference" than that is acceptable. Accordingly, under the low "discriminability" condition, the categorizer should accept Level-3 "sameness", but many "different" responses would be an expression of Level-2 "difference."

In contrast to this, according to Silverman and Goldberg(1975) and Taylor(1976), the number of differing elements on the stimuli was manipulated, and thereby overall complexity was not so varied in their experiments.

In another experiment, Snodgrass(1972) did not find the "fast-same" phenomenon under a simple-pattern condition, although the phenomenon appeared under a complex-pattern condition. However, an inspection of her stimulus patterns (Figure 1 in Snodgrass, 1972) reveals that six patterns of the nine simple patterns are plainly distinguishable. In contrast, all nine complex patterns are very difficult to discriminate from each other. She manipulated complexity, and as a result, manipulation varied discriminability too much. Her results may well be interpreted as an effect of discriminability.

(3) Case C refers to the type of experiment in which string length is more than four while the other factors are the same as that in Case A (complexity is irrelevant). Except for stimulus strings having high familiarity, Level 3 can not simultaneously describe stimulus strings containing more than four letters. The categorizer must accordingly not accept the output from Level 3 but rather that of Level 4 which judges stimulus items on one-by-one basis.

When Level 4 exerts self-terminating letter-by-letter comparisons, the "fast-same" phenomenon will be negative, because it needs to compare all letters for "same" judgments but not for "different" ones. On the other hand, if exhaustive comparisons are done, the degree of positive "fast-same" phenomenon will be found, because each comparison of individual letters will be faster for "same" pairs than for "different" ones.

Using various string lengths, Krueger (1984) found that "same" reaction time increased nearly twice as fast as "different" reaction time with string length. For long strings, "same" responses were slower than "different" ones. This suggest self-terminating letter-by-letter processing (for the mathematical significance of the "twice slope," see Townsend & Ashby, 1983). This experiment contains both Case D and Case C: short lengths and long ones, respectively (see the mathematical model mentioned in Saito, 1997). In Case A (or Case D), the advantage of "same" response is based on the self-terminating description-match search, whereas in Case C the advantage of "different" response is based on the self-terminating letter-by-letter comparisons.

The present theory does not have the property to predict which of the termination rules (self-terminating or exhaustive) is used in this letter-by-letter processing. In Krueger's(1984) Experiment 2, the "fast-same" phenomenon was not found at string lengths of more than four under a certain sequential-presentation condition. However, the overall data under this condition suggested the exhaustive rule. Under this condition, a great upsurge of false "same" response rate appeared (up to about 25 percent), but such a tendency was not found for false "different" responses. Krueger(1984) has suggested that focused rechecking inhibited false "different" responses. If this is true, a more detailed theory and model are needed to predict such data. In mathematical models, this problem of the termination rules is rather complicated (see Townsend & Ashby, 1983, Chap. 7), and future researches are needed.

However, according to the Krueger's data, the self-terminating rule may be assumed in ordinary matching experiments when experiments do not include a certain memorizing performance (long retention interval, at least, above 1000 msec). Discussions mentioned below assume the self-terminating rule in Level-4 performance.

(4) Case D refers to the type of experiment in which the heterogeneity is sufficiently low, the length of letter string is less than five, and the degree of stimulus complexity is not great. In such an experiment, the resolution-level determination depends on "different" pairs used. For example, if all stimulus differences relate to outline shapes, the categorizer can accept both "sameness" and "difference" at Level 2. Since complexity is not too great and heterogeneity is low enough, the subprocess which first finds "difference" usually should be identical.

Because the categorizer accepts identical-level messages during most trials, the "same"-"different" disparity will be greater than in other cases. That is, the "same"-"different" disparity between overt responses is the direct expression of the self-terminating advantage of "same" judgment in a subprocess. Krueger(1986) found this low-heterogeneity effect. (Krueger's, 1978, noisy-operator theory also predicts the effect of the heterogeneity.)

(5) Cases E and F refer to the type of experiment in which Level 3 can not describe stimuli. In such an experiment, Level 4 should be selected based on the identical reason in Case B. Cases B and E are different in heterogeneity from each other, but great complexity is critical: Levels 1, 2, and 3 do not have a resolution level sharp enough to describe such stimuli.

In these cases, the categorizer can accept only output from Level 4 to trigger overt response. The "fast-same" disparity should be either small or negative. For example, if stimuli are Julesz's(1971) patterns used in random-dot stereogram experiments, we may find a difference between the patterns after rather hard work. However, we probably could not put confidence in the sameness found in physically identical patterns even after long careful scrutiny. "Different" responses will thus occur faster than "same" ones.

1.Effect of Description Compactness.

Four experimental variables should affect the compactness of internal descriptions. Both familiarity and good configuration increase compactness. On the other hand, both complexity and long length of letter string (or simple pattern string) decrease it. (1) Level 1 has the lowest resolution level and describes only global stimulus properties. Then, experimental variables, such as familiarity, do not affect compactness in this level's descriptions. (2) Level 2 can describe global shapes; thus, variables affect compactness at this level. However, this effect is smaller than that in Level 3, because this level can not analyze fine inner structure in a stimulus pattern. (3) Lower compactness in descriptions increases latencies at both Level 3 and Level 4. On the one hand, if compactness is high enough, Level 3 can describe long strings of stimulus items.

Level 4 is not affected by stimulus-string length, because of its one-by-one processing. Accordingly, given both the greater length of stimulus string and lesser familiarity, Level-3 latency increases more than Level-4 latency (e.g., strings of unknown or upside-down characters). The probability that Level 3 is slower than Level 4 thus increases; that is, the probability that the categorizer accepts "sameness" at Level 4 increases. Level 4 has a sharper resolution level than Level 3, and hence the categorizer can accept "sameness" at Level 4. In the last section, this possibility was not considered, because experiments using random strings of known letters or shapes were discussed. The determination rule across resolution level is simpler than that in the experiments discussed here.

Given low compactness, the probability distribution of "difference" levels which the categorizer accepts is also skewed to higher resolution levels. This effect, however, is not so large as that of a "same" response, because Level 1 and Level 2, which could trigger "different" response in some trials, are affected less than other subprocesses. Consequently, when these variables are manipulated, mean "same" reaction time is affected more than "different" reaction time, and thus too-low compactness decreases the "fast-same" disparity. On the other hand, high familiarity increases the describable number of letters in Level 3 and enhances the phenomenon. This prediction agrees with the following experimental results. The "fast-same" disparity for stimuli having high familiarity is larger than that for unfamiliar ones; for multiletter matching, in particular, this effect is clearly found (e.g., Egeth & Blecker, 1971; Reagan, 1981; for review, see Krueger, 1975). It should be noted that the compactness of descriptions is far lower for stimulus strings of unknown characters than that of known ones.

When stimulus strings consist of very simple and highly discriminable elements (the digits of '0' and '1'), the present theory predicts that the "fast-same" phenomenon remains for fairly long strings (above four). The digits of '0' and '1' are very simple, and they should be described as elements (or features) within a figure. Level 3 can be used to describe the strings which consist of such digits even when string length is more than four digits. This agrees with Silverman's(1973) data.

Related Phenomena

1.Interactions between Response Types and Some Variables.

Effect of irrelevant surrounding stimuli. When stimuli and irrelevant surrounding stimuli meet, the response types ("same" and "different") interact with similarity between the surrounding stimuli and the targets, or with the asymmetry of the surrounding stimuli (e.g., Eriksen, O'hara, & Eriksen, 1982; Krueger, 1973). In the present theory, the lower level subprocesses automatically describe proximal stimulus items as a group. The lower the resolution level is, the larger the size of a grouping is. These subprocesses hence can not be free from the interfering effect of surrounding stimuli. Of course, this result is task-dependent. That is, when an experimental task is classification, the categorizer can properly use several stressed parts of the descriptions produced by the descriptor. On the other hand, a comparison based only on the stressed parts is unreliable, principally because the correspondence search involves holistic comparison. Stressing in descriptions usually helps description matching, but Levels 1, 2, and 3 can not compare only a part of description separate from irrelevant surrounding materials.

Some irrelevant surrounding stimuli do not destroy the holistic "sameness" of "same" stimulus pairs. For stimuli having such surrounding materials, both the "sameness" and "difference" of Level 3 can be accepted. Each comparison latency increases with the low compactness caused by the surrounding stimuli (smaller value of C, and then smaller a_s and a_d : see Equation 10 in Saito, 1997). However, self-terminating search for "same" judgment is less affected than the exhaustive search for "different," because greater latency is accompanied by larger variance (see Equation 4 in Saito, 1997; each expected value is $1/a$, and its variance is $1/a^2$; the value of a is less than one). "Different" reaction time depends on maximum latency at an individual trial. Here, the greater variance of each latency directly makes the maximum one greater because maximum latency in a trial may be any one of the seven latencies. On the other hand, "same" responses depend on a minimum latency in an individual trial. In contrast to the maximum, the influence of greater variance to this minimum is indirect, because the minimum in a trial is greater only when by chance, all the latencies are greater. These surrounding stimuli, then, affect "different" reaction time more than "same" reaction time.

When another type of irrelevant surrounding material destroys holistic "sameness" of "same" stimulus pairs in Level 3, one must only search for the stressed parts in each description. However, it is difficult to maintain high accuracy. Thus, probability should increase that the categorizer accepts the output from Level 4. This level subprocess performs one-by-one letter matching, and in this situation, "different" responses have a statistical advantage of being self-terminating comparisons. Consequently, this type of surrounding stimulus affects "same" responses more than "different" ones.

This explanation is the counterpart of Proctor's (1981) and Eriksen, O'hara, and Eriksen's (1982) "response competition principle." However, in the present explanation, different effects of surrounding stimulus are produced by the different statistical natures of individual judgments.

Effect of Stimulus Degradation. Degradation of stimulus quality decreases the reliability of descriptions. Such stimulus manipulation does not alter the probability distribution of internal noise and hence decreases signal-noise ratio. The more prominent the effect of noise is, the more visual integration time needed (e.g., Eriksen & Collins, 1967). Consequently, each termination latency of "describing" action increases. Thus manipulation affects "different" responses more than "same" responses. That is, greater latency is accompanied by larger variance. For, as mentioned above, statistically, the increase of each latency in parallel processing affects the exhaustive correspondence search more than the self-terminating search. "Different" reaction times thus increase, and the increment for "different" reaction times is larger than for "same" ones. That is, the greater "fast-same" disparity will be present.

This prediction agrees with the result of Experiment 2 in Saito(1982). When brief flash masking (50 msec) was superimposed on continuously displayed stimuli at an SOA of 100 msec (stimulus onset asynchrony), "different" responses for four letters were affected more than "same" responses, though under a two-letter condition, this interaction was not present.

On the other hand, using parafoveal presentation to produce a degraded stimulus image, Krueger(1985) found that "same" response was affected more than "different" response under the mixed block condition which contained both foveal and parafoveal presentations. This result is incompatible with Saito's(1982) result, since unclear vision inhibits the "fast-same" phenomenon. Probably, this difference between the experiments derived from a difference in criterion setting. In fact, Krueger and Allen(1987) found the greater "fast-same" disparity under a parafoveal-presentation condition in older adult's reaction time. This result is compatible with Saito's(1982) result, since unclear vision produces the greater "fast-same" disparity. In the present theory, it is principally assumed that the judgment criterion is not altered; and this assumption works in explaining other experimental results. However, in the stimulus degradation experiments, this assumption may not be adequate. When stimuli are blurred, a proper criterion setting is difficult.

Size invariant matching. When stimuli to-be-compared differ in size, and subject's task is size-irrelevant matching, reaction time increases with the ratio between stimulus sizes (e.g., Bundesen, & Larsen, 1975; Larsen & Bundesen, 1978; Note that Kubovy & Podgorny, 1981, found no size disparity effect). On the one hand, Kolers, Duchnicky, and Sundstroem(1985) found that though size disparity affected face-recognition accuracy, it did not affect word-recognition accuracy. Consequently, this type of matching poses a serious problem for some theories.

Two cases of size disparity effect in "same"-"different" judgment should be distinguished. One is the effect of absolute size on vision system, and the other is size scaling. If stimuli are rather small, stimulus size will affect the processing time in a basic perceptual system. That is, when a stimulus figure is too small, the system must perform detailed analysis. Therefore when stimulus sizes used are sufficiently small, the processing of smaller stimulus figures takes a longer time. When absolute size difference is fairly large, and the smallest stimulus used is adequate, Level1 triggers a size scaling mechanism.

When Level1 finds size disparity but other attributes do not vary (i.e., linearity or so forth), the subprocess triggers a size-scaling mechanism, as hypothesized by Bundesen and Larsen(1975). In this case, input to the descriptor continuously changes in size.

If "different" stimuli have many common attributes, the categorizer can trigger neither "same" nor "different" responses until size difference becomes negligible. On the other hand, when the stimuli have few common attributes (have many size-irrelevant uncommon attributes), "different" responses can easily be elicited. That is, the existence of size-irrelevant uncommon attributes always confirms difference even when size scaling does not terminate. However, the nonexistence of such attributes does not warrant "sameness," since uncommon features may be found when the size scaling terminates. For example, overall 'circleness' or 'pentagonness' can be compared even when size scaling is yet to be completed. When a stimulus pair has the disparity in 'circleness,' 'pentagonness,' or so forth, the categorizer can trigger a "different" response. On the other hand, even if such properties are equal, this does not warrant that two figures are the same, since when the scaling is terminated, some corresponding lines could differ in length. Accordingly, the strategy of the categorizer is similar to that used in other tasks: That is, any "difference" except size is always acceptable, but "sameness" is not. (cf., Takano, 1987; 1989, proposed that four types of information exist: orientation-independent one, orientation-dependent one, or so forth. He states that we need this classification in order to explain the mental-rotation phenomena.)

The present theory predicts the effects of size disparity as follows. Case A: When "different" pairs have many uncommon size-invariant attributes, interaction between size disparity and response types surfaces. As mentioned above, size disparity will affect "same" reaction time but not affect "different" reaction time. Case B: When "different" pairs have only a small uncommon size-invariant features and stimuli are unfamiliar, size disparity effect will appear in both response types. The descriptor can not properly describe a small number of the size-invariant features. Case C: On the one hand, even when "different" pairs only have a small uncommon size-invariant features, high familiarity will suppress the size disparity effect because even a few size-invariant features can be properly described.

Case A agrees with finding of Besner and Coltheart(1976). Case B also agrees with Larsen and Bundesen(1978) findings. They defined pairs of rotated-same figures as "different," and the figures used were unfamiliar (see Besner, 1983; he confirmed the difference between Case A and Case B). Case C confirms results found by Larsen(1985); he demonstrated that increasing familiarity diminished the size disparity effect.

Theories which assume uni-dimensional pooled information seem to have difficulty in explaining facts related to size invariant matching. Size disparity does not always affect reaction times; in addition, the disparity sometimes interacts with the response types. These facts denies the assumption that a matching device always receives only size modulated information. In such theories, these facts may be explained by either criterion shifts or a prior selection of size invariant information.

However, even when prior analysis of size decides the criteria at an individual trial, such a strategy will produce a number of errors in certain situations. Its reliability is not always constant; that is, it is not feasible that an amount of overall size disparity always yields identical change on a similarity scale. For example, suppose we make some shape differences enlarging half of a figure; this manipulation produces both overall size and shape differences simultaneously. No similarity scale can always depend proportionally on overall size disparity. Consequently, an explanation based on criterion shifts becomes rather complex and difficult.

On the one hand, prior selection of size invariant information is impossible without some prior recognition. Some such recognition mechanism should be added, and a functional relationship between prior recognition and the matching mechanism must be assumed. If such a prior-selection mechanism exists, it can not be a feature-level processor, because Watson(1981) found that geometric illusion could produce the size disparity effect.

Short-term Learning. In the descriptor, neither instruction nor priming manipulation decreases (or increases) the number of "describing" procedures. The system, however, must be able to learn both new "describing" procedures and the setting of default procedures for everyday life.

When stimuli are letter strings, some "describing" procedures used at Level 3 would not be efficient to describe the letter strings. However, as mentioned above, the number of procedures used must not be carelessly decreased. Decreasing the number should be slowly done through experimental sessions. Because the exhaustive search of description correspondences produces the disadvantage of "different" responses, the decrease will diminish the "same"-"different" disparity. (Each procedure is accelerated by reallocation of capacity, and this contributes to overall faster reaction times.) This prediction matches findings of Proctor and Rao(1983, Experiments 1 and 3). They found that the "fast-same" phenomenon within the experimental session 1 was larger than that within session 2.

2.Some Paradoxical Phenomena.

"Slow-physical" phenomenon. Usually physical matching ('AA') is faster than name matching ('Aa') (Posner & Mitchell, 1967; Posner, 1969). It is controversial which code (visual or name) is used in name-identity matching (Boles, 1986; Boles, & Eveland, 1983; Kirsner & Sang, 1979; Kroll & Parks, 1978; Posner, Boies, Eichelman, & Taylor, 1969; Proctor, 1978; Wood, 1974). However, the point should be obvious that recognition system can use both codes: Kirsner and Sang (1979) showed that subjects could retain the visual detail of a letter for four seconds. Under a sequential-presentation condition, Wood (1974) found that two types of letter-pair similarities (aural and visual) interacted with the presentation modalities of the second letter presented.

Because the categorizer is under cognitive control, the subjects can use both types of descriptions properly at the categorizer level. Theoretically speaking, the following finding presents a more important problem. Garner, Podgorny, and Frasca (1982) found that "physical" matching judgment on the number of elements within a stimulus (XI,III,3,10) was slower than "cognitive" matching judgments ('odd-ness' and 'name'). This is the "slow-physical" phenomenon. This phenomenon indicates that the simple theory which states the alternative of visual or name codes is insufficient.

The present theory can easily explain this phenomenon: Levels 1, 2, and 3 of the descriptor can not describe '1' and '0' in the stimulus of '10' as independent objects (see the section of "Effect of Description Compactness"). Consequently, they can not count the number of digits. The stimulus set used contained a Roman digit, 'III,' in particular. The "number of its elements" can not be described by these subprocesses, because this is a cohesive pattern. Since the categorizer can accept only output from Level 4, reaction time will be rather slow. On the other hand, the categorizer, when classifying the name of a pattern, can employ the reports from Level 3. Then, the task of counting the number of elements in a cohesive pattern is more difficult than that of naming patterns.

This is the counterpart of Proctor's(1981) "levels of processing" principle. However, his principle can not explain the "slow-physical" phenomenon, since the principle only states the difference between the physical and name levels.

"Slow-Same" Phenomenon. "Same" reaction time for uni-dimensional stimulus is greater than "different:" i.e., for tone comparison (e.g., Bindra, Donderi, & Nishisato, 1968; Nickerson, 1969). Krueger (1979) explained this "slow-same" phenomenon, using a probability distribution of the difference count. However, the present theory proposes another explanation.

Since the human brain does not have infinite resolution of analysis, the encoding of physical quantity can not have infinite variants. Hence, the number of description variants must be far smaller than that in pattern encoding. Furthermore, an efficient "describing" procedure in any task will be uniquely fixed by the nature of physical quantity judgments. In each subprocess, then, it is sufficient to consider only one "describing" procedure, though the criterion of "same" must be relaxed. The reason for the relaxation is that because of internal noise, a complete "sameness" between descriptions of quantity cannot be expected.

Accordingly we need not consider any complex interaction among the resolution levels nor among different "describing" procedures. When a difference between stimuli is great, Level 1 can recognize "difference" with high confidence. When the difference is small, its output is "same" but not credible. At that time, some higher resolution level must determine a response. For this reason, whereas any-level "difference" is acceptable, only Level-4 "sameness" is reliable. Hence "Same" judgment will be the slowest. It should be noted that when only one procedure is used, the self-terminating advantage of "same" judgment does not exist. Hence, "different" judgment at Level 4 is also faster than "same" judgment. However, when the output function of the basic sensory system is non-linear, this is not true. One example is the vertical and horizontal superiority in line slant matching found by Sukigara(1980).

Reaction time functions against the stimulus difference will not be discrete. The quantity described fluctuates according to internal noise. Consequently, the "difference" level which the categorizer accepts at an individual trial is a probabilistic variable. The function of mean "different" reaction time hence will be continuous.

Word-shape effect. In a proof reading task, Paap, Newsome, and Noel(1984) did not find any effect from "word shape," which is a global outline shape made with proximal letters (Wheeler, 1970). Also, they did not find the effect in a lexical decision task. In contrast, Oden(1984) found an effect that could not be explained by the recognition of each letter. In Oden's experiment, subjects performed a word-choice task, and words used contained letters in which features varied through several steps along a continuum of values.

The theory under consideration explains these results as follows: In a word-choice task, the categorizer may employ both global and local descriptions. In Oden's(1984) experiment, subjects chose a word from two alternatives (*water/watch* or *erase/chase*): the pairs have word-shape differences. Global information should facilitate decisions by the categorizer, and "word shape" will affcct overt responses. Because, in this experiment, judgment was based on the identification of a fuzzy letter form (*e/c* or *r/h*: *e* or *r* can be continuously transformed to *c* or *h*, respectively), subjects must decide whether ambiguous letters are *e* or *c* (*r* or *h*). Level-3 descriptions, then, would not be helpful, since Level 3 does not produce letter-by-letter descriptions. Because critical letters are fuzzy, it is difficult for the categorizer to identify the fuzzy letters embedded in Level-3 "word" descriptions. That is, the identification of such words including fuzzy letters are also fuzzy, and hence it is better for the categorizer to accept Level-4 local descriptions and Level-2 "word shape" descriptions.

This explains the fact that the effect of spelling pattern did not appear in this experiment (spelling patterns are used by Level 3). A word superiority effect appears, provided a letter probe is used, and the effect depends on spelling patterns (e.g., Spoehr & Smith, 1975). Note that in such experiments, letters used were not fuzzy. These are presented very briefly, and the number of different stimuli is larger than in Oden(1984). Also the probe letters are presented after stimulus-word presentation (see below).

In the lexical decision task, response alternatives were not presented, and the task was discrimination between words and nonwords. Thereby, word shapes were not so helpful, since nonwords also can have the identical word shape. It should be noted that the number of different stimuli were three hundred sixty. When the number of alternative words is small and the subjects know the alternatives, "word shape" differences would be useful information. However, when the number is large, "word shape" differences recognized does not sufficiently reduce entropy of the pool of possible words. The categorizer was then forced not to use Level-2 information. In Oden's(1984) experiment, four words and ninety four fuzzy words were used. The fuzzy ones were more or less similar to two of the four words. The subjects tried to judge which of the two was similar to a given stimulus. Since a small number of judgment alternatives was given, "word shape" proved useful.

When the task is proof reading, the categorizer should select output from Level4, because letter-by-letter scrutiny is needed; though to some degree, Level-3 information might be used. Then the word shape effect does not appear.

Note that in contrast to subjects in Paap et al (1984), Oden's(1984) subjects knew response alternatives before seeing a stimulus. In Silverman's(1974) high "discriminability" condition mentioned in "Strategies employed by the categorizer," subjects could know that when finding an outline-shape difference, they could respond "different," because of the experimental design. That is, the categorizer must accept a type of information only when that information sufficiently restricts the number of possibilities which could be considered. Otherwise, responses become erratic, or such processing exhausts great resources. The specific purpose of a given behavior determines whether the restriction is sufficient or not. In reading, context restricts the number of responses, but the effect of this restriction depends on the reading purpose: shimming or intensive reading (see below).

Speed-accuracy tradeoffs. If hard speed is stressed, "false-same" errors will increase more than "false-different" ones. In such cases, subjects must rely on a lower resolution level. In ordinary experiments, however, neither "sameness" at Level 1 nor at Level 2 is adequate for "same" response as defined by the experimenter. In other words, these subprocesses judge many similar "different" stimulus pairs to be "same." If the categorizer accepts their "sameness," overt responses are accordingly "false-same" errors on "different" trials. This prediction matches Krueger and Chignell's(1985) results.

It should be noted that reliability disparity is purpose-relevant: When "sameness" at Level 3 is needed, "sameness" at Level 2 (or Level 1) is not credible. If, however, Level-2 "sameness" is needed (global "sameness"), its output is reliable.

On the other hand, if subjects are instructed to respond to a type of stimulus pair ("same" or "different") only when having absolute confidence, the categorizer must rely on a higher resolution level. Also in this case, this instruction will alter "same" and "different" responses. That is, even under the "cautious-different" condition, some low resolution level may yet judge some difference for pairs having high dissimilarity. This "difference" is reliable. On the one hand, under the "cautious same" condition, the system must select only higher resolution-level "sameness" because "sameness" in these experiments is the unique concept. Consequently, the disparity between the "cautious-same" and "cautious-different" conditions becomes greater for "same" responses than that for "different" ones. In addition, the instruction disparity will be smaller for dissimilar "different" pairs than that for similar ones.

The results of Ratcliff and Hacker's (1981) Experiment 1 confirms these predictions. They found that at "same" trials, the disparity between the "cautious-same" and "cautious-different" conditions was 101 msec. The disparity at "different" trials were 90 msec under the one-letter-different condition, 67 msec under the two-letter-different one, 51 msec under the three-letter- different one, and 57 msec under the four-letter-different one. Clearly, the higher the similarity of the "different" pair is, the greater the effect of this instruction becomes. The effect on "same" response is the greatest. (Proctor, Rao, & Hurst, 1984, reconfirmed this phenomenon.)

It should be noted that the function of speed-accuracy tradeoff will not be discrete, since the latency of each level is a probabilistic variable. The expected value for reaction time within an error range is the weighted sum of several resolution-levels latencies. Thus, the function of mean reaction time will not be discrete.

Disjunctive task. In the disjunctive task (see Farell, 1985), "same" responses must be elicited when any of relevant dimensions or some letters within stimulus strings is the same. That is, "different" responses in this task must be elicited only when all dimensions (or letters) are different.

The present theory predicts the "fast-same" phenomenon in this task, as follows: Only Level4 can describe elements of figures (or letter strings) in a one-by-one manner and find partial "sameness." Because automatic grouping is present, the holistic matching at Level 3 can not find partial sameness, as mentioned in "Effect of irrelevant surround." "Same" judgment in this task is thus mediated by self-terminating letter-by-letter comparisons, and "different" judgment necessarily is exhaustive. "Same" responses will then usually be faster than "different" responses. Furthermore, since processing at Level4 is the slowest, reaction time values in this task will be larger than that in the ordinary conjunctive "same"-"different" judgment tasks. These predictions concur with Derks'(1972) results. In the disjunctive task, "different" reaction time was slowest, and "same" reaction time decreased with the number of critical dimensions. Besides, these reaction times were greater than that in the conjunctive task. (See Figure2 in Farell, 1985. He replotted these data so that inspection might be easier. Please note that in his figure, conjunctive and disjunctive reaction times are plotted on different scales.)

Conclusion

The purpose of the present theory is to explain matching phenomena and to provide links between them and our knowledge regarding perception and cognition. Furthermore, another important purpose is to show that a certain principle works. The principle states that in most cases, reaction times and error rates do not depend on quantitative judgment-criteria settings but on stimulus-dependent factors and strategies. The strategies relate the decision rules across viewpoints and on other decision rules across resolution levels of analysis. A different quantitative-criterion setting is needed only when degraded stimuli are used, or when physical quantity matchings are forced.

To explain fast recognition performance, the present theory assumes multiple descriptions which are based on various viewpoints. The four resolution levels of analysis, the levels of detail, are assumed, based on Palmer's(1975;1977;1985) investigations. The main frame of the theory involves nested parallel processing: Each of the four subprocesses which have different resolution levels produces multiple descriptions based on different viewpoint analyses. A categorizer uses the descriptions produced by the subprocesses and categorizes stimulation patterns. Krueger's (1978) theorem also should be considered. He states that internal noise is more likely to produce spurious featural mismatches than matches. Accordingly it is assumed that "same" judgment in each subprocess is a result of self-terminating description-correspondence search while "different" judgment results from exhaustive search. Therefore, four types of "sameness" and "difference" are judged based on different resolution-level analyses.

In Saito (1997), a mathematical model based on the theory was fitted to the data from two experiments. The purpose of this model is to demonstrate quantitatively the following four assumptions: (1) decision rules across different-viewpoint descriptions explains the "same"-"different" disparity; (2) compactness of descriptions explains the effect of letter-string length; (3) priming explains the disparity between sequential and simultaneous presentation methods (a Proctor's, 1981, principle); (4) the limit for describable string length is four at Level 3. The model worked in predicting both reaction times and error rates, though predicted standard deviations were larger than observed data.

In this paper, strategies which the categorizer ought to select were discussed to predict other phenomena. Experimental manipulation and the characteristic of judgment forced by instruction determine a strategy. Accordingly, matching experiments were classified into six types. Also, it was demonstrated that the theory works not only when qualitatively predicting matching phenomena but also numerous other phenomenon such as effects of familiarity, irrelevant surrounding, and stimulus degradation as well as size invariant matching, effects of short-term learning, mental set, "slow-physical" and "slow-same" phenomena, word-shape effect, speed-accuracy tradeoffs, and disjunctive task.

The phenomenal world of humans is very complicated. Hence, when an observer has a different purpose for making judgment and deciding behavior, each type of information in a given circumstance takes on different meaning and significance. Accordingly, theories would be problematic which have only elemental feature comparison based on some uni-dimensional pooling of information. The nested multiple-description theory points out that because the characteristic of meaning and significance exists, certain aspects of human judgment can not be explained by quantitative-criteria selections. Rather they are understood by decision rules across viewpoints and on other decision rules across resolution levels of analysis.

Abstract

The theory proposed by Saito (1996;1997) is discussed which assumes multiple-description, search for correspondence between descriptions, multiple resolution levels of analysis, priming, and a categorization system. The self-terminating correspondence-search hypothesis explains the "fast-same" phenomenon. Some paradoxical data, the "slow-physical" phenomenon, for example, are explained, and a processing principle is demonstrated from these: The principle states that reaction times and error rates do not depend on quantitative judgment-criteria settings but on decision rules across description viewpoints and on differing decision rules across resolution levels of analysis.

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