

# Is Activation of Different Codes Related to Age and Stimulus Material?

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The activation of different codes as related to age and stimulus material was studied using a same/different classification task. Two age levels (6.5 and 10.6) and two kinds of stimuli were considered. Response latencies and errors were evaluated for pairs of letters and geometrical figures, tachistoscopically presented. For both types of material same responses were given to physical identity pairs, analogue identity pairs, and name identity pairs. The results show that: (1) the nature of the stimuli affects the types of codes activated where higher-order operations are required to compare the stimuli; (2) the level of accuracy changes as a function of age for both types of stimuli.

In recent years there has been a great deal of interest in the process by which one reads words. Many of the experiments on reading have described this complex skill through a series of processing stages (LaBerge and Samuels, 1974) and have tried to differentiate the codes by which a word is represented. A visual word activates at least visual, phonetic, and semantic codes and some operations take place within each code.

According to some authors (Gibson, Shurcliff, and Yonas, 1970; Johnson, 1975), the visual code is a sufficient basis for reaching semantic levels of processing and for handling the activation of higher-level semantic analysis. Other studies seem to demonstrate that access to the semantic level of processing has to be mediated by a phonological code, that is, by a phonetic representation (Stanovitch and Bauer, 1978). To summarize, experimental evidence suggests that both types of codes—visual and phonological—play an integral part in reading processes (see for a review McCusker, Hillinger, and Bias, 1981) and that, since visually mediated access is assumed to be more rapid, it is more likely to be the representation of choice (e.g., Coltheart, Davelaar, Jonasson, and Besner, 1977; Marshall, 1976).

In order to read fluently, one must identify and discriminate among letters (Gibson, 1969). Following these considerations on the primacy of the visual code in representing letters and words and in reading, it seems reasonable to consider those studies concerned with the acquisition of letter processing, in order to have a better understanding of reading disorders. Tracing the nature of the codes activated and the

time-course of letter processing may help in identifying the levels at which these disorders take place.

Reading disabilities may be due to impairments in the processing of the visual code. This means that subjects may have difficulty in carrying out operations on that code, e.g., difficulties in visual orientation (for a review see, for example, Vernon, 1971). However, other studies have demonstrated that a typical reversal, such as b/d, may be the result of confusion in the production of the name code (Ellis and Miles, 1978). It is suggested that dyslexic problems in reading and spelling cannot be ascribed only to a visual code problem, but that they are attributable to deficits in the translations of visual stimuli into their name code equivalents.

While for letters isolating these two processes is difficult, non-alphanumerical stimuli are a more suitable material for differentiating the process of abstraction of visuo-spatial characteristics from that of name attribution. Two geometrical figures as, for instance, two triangles of different shapes, may be compared either on the basis of their common spatial rule or on that of their common name (Proctor, 1981). On the contrary, for two cross-case "a's" (i.e., Aa), the only rule linking the two letters is their phonetic code. The visual and phonetic codes are two independent systems working in parallel and their time-course relies on the operations carried out within each of them (Posner, 1978). For these reasons, comparison of letters and geometrical figures at different levels of processing allows us to isolate the operations carried out within each code for the two types of material and to identify the nature of the codes activated. If the phonetic code works for both types of stimuli, no difference will be found between letters and geometrical figures. On the contrary, if the phonetic code is active only for letters, a different trend related to the materials will have to be found.

The present study attempts to investigate if children at different age levels can activate different codes to compare alphanumerical and non-alphanumerical material, and if they can perform operations within each code with the same proficiency at different age levels. These questions arise from those studies that have shown differences in response latencies related to stimulus material (see Proctor, 1981) and to age (Reitsma, 1978). Posner's technique seems very suitable for testing these hypotheses since it is possible to isolate the stages of visual information processing and to define the codes on which different operations take place, both for letters (Posner and Mitchell, 1967; Posner, 1978), and for geometrical figures (Bagnara, Roncato, Simion, and Umiltà, 1978).

Posner's approach rests on the temporal hierarchy found in response latencies. Reaction times (RTs) are faster when the two letters are physically identical (PI matches: AA) than when they have same shape but are different in size (analogue identity, AI matches: Aa). RTs are even slower when the two letters only share the same name (name identity, NI matches: Aa).

The concept of processing levels was applied to this hierarchy where each successive level serves to produce a more abstract code. If the task requires comparison of

two physically identical letters, they are classified as same on the basis of the visual code, whereas when they only share the same name, they are matched on the basis of a phonetic code. The analogue match takes place on the basis of the visual code after an operation of normalization of one of the two letters.

Our hypothesis predicts that children activate the visual code and perform automatic operations on it with the same proficiency at all age levels and independently of the type of stimulus material. This is because alphanumerical and non-alphanumerical material, visually presented, activate the visual code and the same operations take place on it when comparing both types of stimuli. Consequently, we can expect that the time difference between PI and AI matches does not vary as a function of age and stimulus material.

As far as the name level of processing is concerned, our assumption is that different codes are activated for alphanumerical and non-alphanumerical material. Letters can be compared only on the basis of the phonetic code, while pictures can be compared on a higher-order spatial code. In both cases the activation of these codes depends on learning. For letters, the correspondence between a grapheme and a phoneme is determined by the conventions of a given society (Gibson, 1969). For pictures, although the spatial rule allowing us to consider two objects as belonging to the same category is always visually present, this rule usually has to be learned.

So we can predict for both types of material an age-dependent effect at the so-called "name level". To retrieve the phonetic information (i.e., to activate the phonetic code and discover the spatial rule) we benefit from learning and practice. Consequently, we may expect that the time difference between PI and NI matches varies as a function of age for both types of stimuli.

To summarize, we predict that there will be: (1) no age-dependent effect for operations carried out on the visual code, either for letters or for figures; (2) an age-dependent effect for operations taking place on either the phonetic or the spatial code, because access to both codes depends on learning.

## Method

One experiment was carried out to test these hypotheses. Children at two different age levels (6.5 and 10.6 years) were given a simultaneous same-different classification task. Both their response latencies and errors were recorded. Two types of stimuli were employed: letters and geometrical figures. Both types of stimuli were selected because they had already been tested on adults.

**Subjects.** Subjects were 80 children in two grade levels, 40 each in the first and fifth grades. They were tested individually. Mean age for the first graders was 6.5 (range 6.2 to 7.3) and for the fifth graders 10.6 (range 9.7 to 10.11). All the children were selected from a suburban middle-class elementary school. In each group 20 were males and 20 females. All subjects were tested towards the end of the school year. At each grade level half the subjects were tested with letters and half with geometrical figures.

**Stimulus material.** The stimuli were pairs of letters and geometrical figures. The style chosen for letters was Gill Extrabold (RP series of R41). Photographic negatives (35mm) of each pattern were mounted in slide-holders for tachistoscopic projection on a back projection screen. The pairs of letters were obtained by two vowels: A and E. The letters were of two different sizes and were placed one above the other so as to eliminate horizontal scanning effects (Bryden, 1966). Same responses could be given to physically identical letters (PI matches), to letters identical in shape but different in size (AI matches), and to letters that shared the same name but were printed in different typecases (NI matches). Different responses were given to letters differing in name (e.g., A E) (see Figure 1).

Thirty-two pairs required a different response and 48 a same response. Of the same stimuli, one-third were PI, one-third AI, and one-third NI matches. Upper-cases and lower-cases of two different sizes were used. Size, typecase, and position of the letters in the pairs were counterbalanced so that they could not be used as classification cues.

For the geometrical figures, the stimuli used were triangles and trapezoids. Eighty pairs were obtained from six geometrical figures: isosceles, scalene, and right-angled triangles and trapezoids. The stimulus material for geometrical figures is shown in Figure 2. Figures could have two possible sizes, and were placed one above the other. Physical matches were obtained by presenting two figures of the same shape and size (e.g., two scalene triangles of the same size), analogue matches were obtained with two figures of the same shape but differing in size (e.g., two right-angled triangles of different sizes), and name matches by combining two figures differing in shape (e.g., a right-angled and a scalene trapezoid).

Different pairs were obtained by combining a triangle and a trapezoid. In the 80 slides, 32 pairs required a different response, 48 a same response.

**Procedure.** Stimuli were back-projected on a screen in random order. They were presented binocularly and centrally for 200 msec. An acoustic signal prompted subjects to fixate a central point on the screen. Subjects were asked to judge whether the two elements of a pair were the same or different, by pressing one of the two keys on the response panel with the index fingers of both hands. Half the subjects used their right index fingers for same responses and left ones for different responses, and half followed the reverse arrangement. Pressing the keys stopped one of two electronic millisecond counters that started at the beginning of each 200-msec. exposure period. In the case of letters, subjects were instructed orally to respond same if the two letters had the same name, irrespective of size and case, and to respond different if they did not have the same name.

In the case of figures, for the younger subjects who did not know the names of the geometrical figures, the tachistoscopic task was preceded by a session during which they were taught to discriminate between the two classes of figures. Line drawings of pairs of figures were presented to the children. The classification rule was never explained to subjects, but feedback was given on the correctness of the

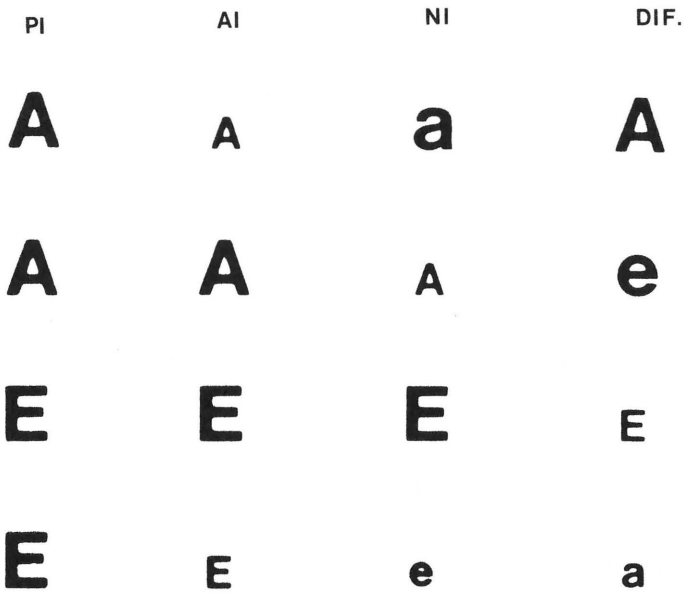
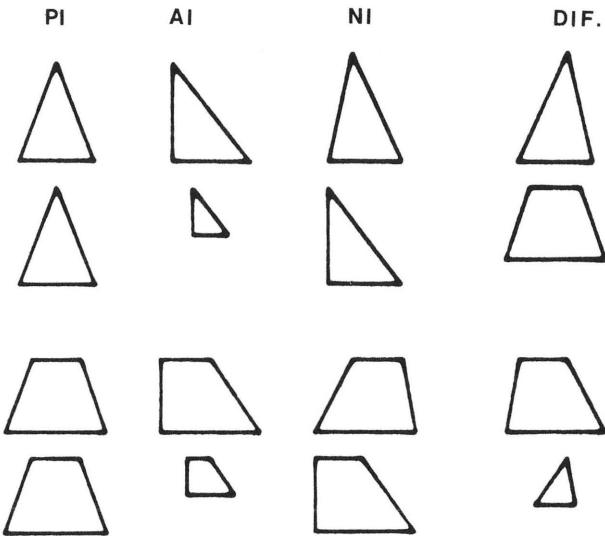


Figure 1. Examples of physical identity (PI), analogue identity (AI), name identity (NI) and different (Diff.) pairs.

Figure 2. Examples of geometrical figures employed: a) physical identity matches; b) analogue identity matches; c) name identity matches; d) different pairs.



choice. The training session lasted until subjects answered five consecutive presentations correctly. The older subjects were instructed to respond same or different on the basis of name, irrespective of shape or size. With both kinds of material the subjects were tested in one session lasting about 90 minutes. Four blocks of 20 trials each were presented, separated by a 5-min rest period. Subjects were instructed to press the keys as quickly as possible, trying to avoid errors. If they made an error or their response latency exceeded an arbitrarily set limit of 2 sec., the trial was replaced.

### General Results

A summary of mean RTs and errors for both types of materials is shown in Table I. The mean same RTs were submitted to a  $2 \times 2 \times 2 \times 3$  mixed ANOVA with Age (first grade vs. fifth grade), Sex (male vs. female) and Stimuli (letters vs. geometrical figures) as between subjects factors, and Type of matches (PI, AI, NI matches) as within subjects factor.

Two main effects reached statistical significance: Age,  $F(1,72) = 62.51$ ,  $p > .001$ : younger children were 258 msec slower than older ones in processing the stimuli (958 vs. 710 msec). Type of match,  $F(2,144) = 113.17$ ,  $p > .001$ : the three levels of processing were also found for children. Subjects were 192 msec faster to compare two physically identical stimuli than to compare two stimuli differing at the name level (744 vs. 936 msec). The analogue match was 78 msec slower than the PI match (822 vs. 744 msec), and 114 msec faster than the NI match (822 vs. 936 msec). The first-order interaction Stimuli  $\times$  Type of match also reached statistical significance,  $F(2,144) = 7.02$ ,  $p > .005$ . The pattern of this interaction is shown in Figure 3. This interaction is due to the different response latencies of the two types of stimuli at the three levels of processing. Letters and figures do not differ significantly at the PI level (752 msec for letters vs. 736 for figures) and at the AI level (841 msec for letters and 803 for figures). The only significant difference is at the third level of processing, i.e., the name level (990 msec for letters vs. 882 for figures). The Newman-Keuls test (Myers, 1972) was significant:  $p > .01$  only for this last comparison.

The ANOVA with the same four factors carried out on error data complements the corresponding effects in RT data (see Table 1). Two main effects are significant. The main effect Age,  $F(1,72) = 8.69$ ,  $p > .005$ , shows that accuracy increases as a function of age. Older children make fewer errors than younger (6% vs. 10%). The main effect Type of match,  $F(2,144) = 70.72$ ,  $p > .001$ , indicates that the percentage of errors increases as a function of levels of processing (PI = 2%; AI = 7%, NI = 15%). Also, two first-order interactions reached statistical significance. The first, Age  $\times$  Type of match,  $F(2,144) = 8.63$ ,  $p > .001$ , demonstrates that the percentage of errors at the third level of processing is higher for younger (19%) than for older children (10%). The second significant interaction was Stimuli  $\times$  Type of match,  $F(2,144) = 6.89$ ,  $p > .005$ . The percentage of errors is nearly the same at the first

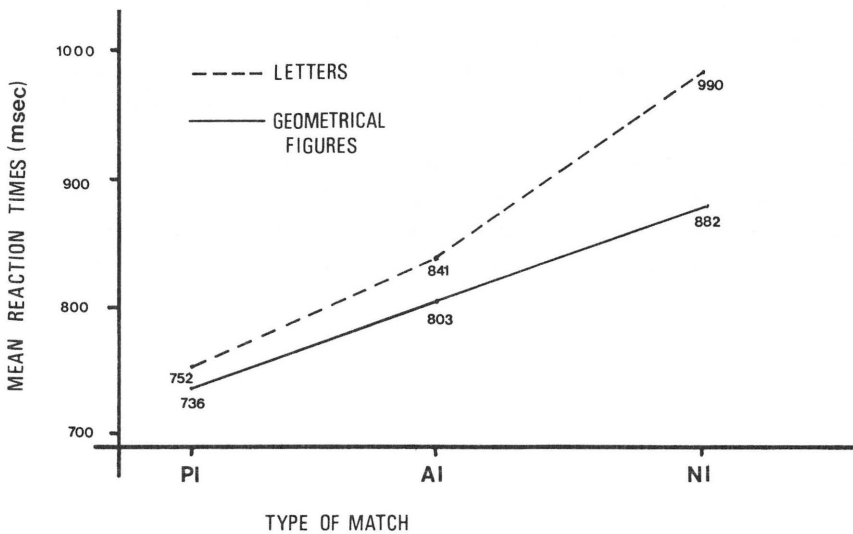
Table I. Mean overall reaction times and errors as a function of Age, Stimuli, Type of match, and Type of response.

	Letters		M
	First Grade	Fifth Grade	
Same			
PI	871 (1.8%)	633 (.9%)	752 (1%)
AI	971 (5.9%)	710 (4.6%)	841 (5%)
NI	1121 (19.6%)	860 (14%)	990 (17%)
M	987 (9%)	734 (6.5%)	861 (7.7%)
Different	1188 (11.5%)	876 (7%)	1032 (9.2%)

	Geometrical Figures			Overall
	First Grade	Fifth Grade	M	
Same				
PI	852 (3.7%)	620 (3%)	736 (3%)	744 (2%)
AI	909 (9%)	697 (6.8%)	803 (8%)	822 (7%)
NI	1027 (18.4%)	738 (6.5%)	882 (12%)	936 (15%)
M	929 (10.3%)	685 (5.5%)	807 (7.9%)	834 (8%)
Different	1082 (17%)	790 (4.3%)	936 (10.6%)	984 (9.9%)

Figure 3. Mean overall reaction times as a function of Stimuli and Type of match.



two levels of processing (PI and AI matches), but at the third level a significantly higher percentage of errors for letters as compared to figures was found (17% for letters vs. 12% for figures). The Newman-Keuls test proves the significance of this difference ( $p > .01$ ).

A three-way between subjects analysis of variance was carried out on different responses. The three factors were Sex, Age, and Stimuli (letters vs. geometrical figures). Two main effects reached statistical significance: Age,  $F(1,72) = 67.81$ ,  $p > .001$ , and Stimuli,  $F(1,72) = 6.76$ ,  $p > .025$ . Older children were 302 msec faster than younger (1135 msec vs. 833). Furthermore, the second main effect shows that figures are processed 96 msec faster than letters (936 msec vs. 1032). The same analysis carried out on errors showed only the significant main effect Age,  $F(1,72) = 17.80$ ,  $p > .001$ . Younger children are less accurate than older (14% vs. 6%).

### Conclusion

The most important result of this analysis was that Posner's paradigm was replicated for both letters and geometrical figures with children as subjects. Changes in efficiency for both letters and geometrical figures are found as a function of age for both same and different responses. Older children respond faster than younger. These results confirm previous studies on children's RTs task showing speed differences in processing visual information (for a review, see Wickens, 1974). Also the findings that same responses are faster than different is consistent with previous studies on tachistoscopic presentation carried out with children (Krueger, 1973).

The interaction between stimuli and type of match for both response latencies and errors showed that at the first two levels of processing (PI and AI matches) children have the same trends for both types of material while at the third level they differ. This finding supports our hypothesis that, independently of types of stimulus material, the visual code is automatically activated and the same operations are carried out within it. The time-course of operation of normalization does not change as a function of the different nature of the stimuli. As for the third level of processing, the so-called "name level", the results demonstrate that operations on different codes are performed for letters and geometrical figures: the former activate the phonetic code while the latter activate the visuo-spatial code. When a higher-order level of processing is required to compare letters and geometrical figures two different codes are activated and different operations take place within each of them.

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