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Visual representations of words in perceptual and image modes as a function of age

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The visual representation of words in percept, image, and mixed modes is studied as a function of age. Response time results support the hypothesis that perceptual representation matures at an earlier age than the more cognitive image representation. Correlations of response times support the hypothesis that perceptual and image representations initially draw on a common general-purpose information processing capacity that differentiates and becomes more specialized (less correlated) with age.

Relatively little seems to be known about the distinctly *visual* representation of words in memory, as opposed to the frequent studies of phonological and semantic representations (Gibson, 1975). However, Weber and Harnish (1974) have made a preliminary foray into the study of the visual representation of words by comparing visual information extraction times from words that are perceptually present vs. words that are present only in visual imagination. One comparison showed little difference between processing times for percept and image representations for three-letter words. It is as though the image system is capable of representations similar in at least some respects to the perceptual system as long as the capacity of the image system is not exceeded.

The Weber and Harnish (1974) task is used here with modification (Weber, Kelley, & Little, 1972), and it has several desirable features. It allows for fairly direct examination of visual information representation ranging from a perceptual through a more cognitive imagery representation, as well as an intermediate mixed representation. It also avoids potential pitfalls by having the same response requirements for all representation modes and by having comparable or isomorphic materials in each mode. In this paper we will assume that part of the normal visual memory representation of words is captured in slow motion by having subjects form a visual image of the word and then extract spatial features from the image. We will call this the correspondence assumption, since it posits a correspondence between visual imagery and visual perception through a common visual memory. We will use the basic task of Weber and Harnish together with the correspondence assumption to test several classes of hypotheses relating visual imagery/perception to age and cognitive growth. The first class of hypotheses deals with the nature of perceptual and cognitive growth. The second class of hypotheses deals with changes in the interdependence or correlation between visual perception and cognition with increasing age.

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TIME DIFFERENCES AND COGNITIVE GROWTH

Perception First Hypothesis

Perceptual functioning matures (stabilizes or reaches a given percentage of asymptote) before cognitive functioning. Beyond a certain age there will be relatively little improvement in perceptual representation time as opposed to relatively more improvement in cognitive representation. This would occur because perceptual processes reach maturity at an earlier age than cognitive processes. Thus, an Age by Representation Mode interaction is predicted, with the response time by age function flatter for the perceptual than for the more cognitive imagery function.

Same Time Hypothesis

Perceptual and cognitive functioning mature (stabilize) at the same time. With increasing age the improvement in performance time associated with perceptual and image representation will be relatively unchanged because perceptual and cognitive representations mature at the same rate. Thus, no Age by Representation Mode interaction would be predicted. A third possibility, that cognitive imagery representation matures before perceptual representation, is not considered. Both of the hypotheses offered assume that perceptual and imagery representation issue from growth functions with similar forms, that may, however, have different asymptotes and growth rates.

TIME CORRELATIONS AND AGE

Divergence Hypothesis

The divergence hypothesis of perceptual-cognitive growth would state that percept-image correlations would be higher for children than for adults. This would be caused by perceptual and cognitive abilities being more closely yoked, or less differentiated, in younger people. Thus, perceptual and image representations might both draw on a general-purpose processing and representation capacity that had not become differentiated for specialized functioning. But with increasing age, perceptual and cognitive representation would become more specialized, differentiated, and independent, that is, less correlated with increasing age. The idea of capacity becoming more differentiated with age is a common view in the mental testing literature (Anastasi, 1970).

Convergence Hypothesis

The convergence hypothesis of perceptual-cognitive growth would state that perceptual and cognitive systems develop independently but become more closely articulated or interfaced with increasing age. This hypothesis seems to be at least equally plausible on intuitive grounds.

METHOD

Subjects

The subjects were 15 normal children (age range 9-11 years) and 15 university students (age range 20-28 years). (The two age populations are probably not equated on all variables except age. But this does not seem critical since interactions rather than main effects are of primary importance.) All subjects were experimentally naive volunteers with normal or corrected vision. Each subject was tested individually by the same experimenter.

Stimuli and Procedure

Each subject was given preliminary training in classifying lowercase letters as to whether they were vertically large (b, d, f, g, h, j, . . . y) or not (a, c, e, i, m, . . . z). The subject was required to orally respond "Yes" to a letter that was vertically large and "No" to other letters. The target letters appeared in the first or last letter position of stimulus words.

The words were taken from a first-grade reader and arranged in six meaningful sentences. Each sentence had six different words. A total of 35 different words was used. One word inadvertently was used twice.

The stimulus words were employed in the following six conditions: (image, percept, or mixed) by (first or last letter location responded to). For the image condition, the experimenter spoke the sentence, and the subject was instructed to repeat the sentence aloud. After the subject had repeated the sentence, the experimenter said either "first" or "last," indicating to which letter location in the word the subject should respond. Thus, for the sentence "A big red bird ate them," the correct oral response sequence for the *first* letter location in each word would be "No, Yes, No, Yes, No, Yes." For the *last* letter location in each word the correct response sequence would be "No, Yes, Yes, Yes, No, No." (The single-letter word "a" is considered to have both a first and a last position.) The image condition thus draws on an imagined memorial representation of the sentence. The principal dependent variable was response time defined from onset of the "first/last" cue to completion of the string of six yes/no responses for a given sentence. This was timed by the experimenter with a stopwatch. For the percept condition the subject orally read the sentence from a 3 x 5 in. card which remained visually available to him during the trial. All the letters were in lowercase type. After the subject had finished reading the sentence, the experimenter said "first" or "last." For the mixed condition elements of perceptual and image conditions were combined. All the letters were presented in uppercase type. The procedure was identical to that in the percept condition, except that the subject had to "translate" in imagination to the corresponding lowercase representation on which his responses were to be based.

All subjects were instructed to respond as rapidly as possible with 100% accuracy. If errors occurred or if the subject blocked on a sentence, no times were recorded for that trial; it was simply rerun at the end of a block. Since errors and response time on a task like this are positively correlated, the correction procedure will introduce a repetition effect and thereby tend to produce conservative differences.

Design

The design consisted of 2 ages (children, adults) by 3 modes of representation (imagery, percept, and mixed) by 2 target locations (first, last position). Age was a between-subjects variable; all other treatments were within subjects. There were six blocks of trials. Each trial block had six sentences, one for each within-subjects condition, and across blocks each sentence appeared in each of the six conditions to constitute a Latin square of conditions by sentences.

RESULTS AND DISCUSSION

Figure 1 shows the principal results, with mean response time per sentence shown as a function of age and condition. An analysis of variance for 2 ages by 3 representation modes by 2 locations indicated a significant age effect [$F(1,28) = 75.87$, $p < .001$], a significant representation mode effect [$F(2,56) = 365.33$, $p < .0001$], a significant Representation Mode by Location interaction [$F(2,56) = 10.36$, $p < .0003$], and, most important, a significant Age by Representation Mode interaction [$F(2,56) = 51.68$, $p < .001$]. No other significant effects ($p \leqslant .05$) occurred.

The major results of Figure 1 are as follows. The representation mode effect indicates that for the present task perceptual representation allows much more rapid processing than the more cognitive image representation. This is consistent with Weber and Harnish (1974) when capacity is taxed. The mixed representation is intermediate in processing time. The important interaction of Representation Mode by Age indicates that the perceptual function is relatively flatter than the more cognitive image function. It also indicates that, of the time change hypotheses described, these findings are consistent only with the perception first hypothesis that the perceptual representational system attains developmental maturity before the cognitive representational system.

Table 1 depicts a Pearson product-moment correlation matrix of conditions. Each subject's mean response

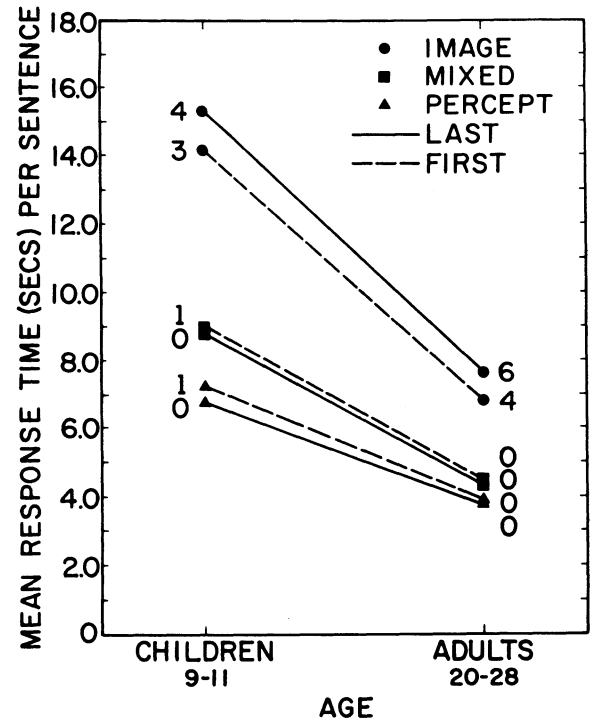

Figure 1. Mean response time per sentence as a function of age and condition. Total errors out of a possible 90 (15 subjects by 6 blocks) are shown beside each condition.

time for a given condition served as the dependent variable. The upper right-hand region of the table presents the correlation coefficients for children, and the lower left-hand region contains the adult correlations. For children all of the correlations were significant ($p < .05$), with individual correlations ranging from a high of .96 (the P-F/P-L comparison) to a low of .62 (the I-L/P-L comparison and the I-L/M-L comparison). For adults the correlations are lower and very often not significant. They range from a high of .78 (for the M-F/M-L comparison) to a low of .11 (for the I-F/M-L comparison). For both children and adults, time correlations tend to be high when comparing first and last letter locations within a given mode of representation.

There are at least two ways of interpreting the difference in correlation matrices for children and adults. The variability interpretation would hold that the correlations for adults are lower than for children because of a more restricted range for adults. The SDs of response time for adults varied from .34 for Condition P-F to .97 for Condition I-F; for children SDs varied from 1.54 for P-L to 3.34 for I-F. The numbers in parentheses below each correlation in Table 1 represent the SDs for the row and column conditions, respectively. The correlation differences between adults and children are unlikely to be due solely to range restriction, because there are some fairly high r values in the adult group that have relatively low SDs (e.g., for P-F – P-L, product-moment r = .69). In fact, if the r values of Table 1 are correlated with the smallest of the two SDs that contribute to the correlation, then for children r (r in table, smallest SD) = –.11. Such a result is most unlikely if a restricted range is serving to depress the observed correlations between times. For adults r (r in table, smallest SD) = .24, a fairly low value accounting for 6% of the variance. Incidently, if the r values in the table are also correlated with either the largest SD or the average of the two SDs that contribute, no evidence in favor of a restricted range interpretation is found. Another reason for rejecting the adequacy of the range restriction interpretation is that the range of r values in the table is much greater for the adult than for the child matrix (.11 to .78 for adults and .62 to .96 for children), even though the SDs for the childrens' data are larger. If a restricted range was controlling the magnitude of the correlations for adults, it is not likely that there would be such a large range of r values.

The growth differentiation interpretation would say that the interrelationship of perceptual and cognitive processes, as measured by their intercorrelations, changes with age. In the child the perceptual and cogni-

Table 1
Correlation Matrix: Upper Right, Children; Lower Left, Adults

	I-F	I-L	P-F	P-L	M-F	M-L
Image First		.75** (3.34,2.79)	.82*** (3.34,1.82)	.74** (3.34,1.54)	.89*** (3.34,2.40)	.84*** (3.34,2.42)
Image Last	.71** (.92,.97)		.66** (2.79,1.82)	.62* (2.79,1.54)	.76** (2.79,2.40)	.62* (2.79,2.42)
Percept First	.43 (.34,.97)	.49 (.34, .92)		.96*** (1.82,1.54)	.88*** (1.82,2.40)	.87*** (1.82,2.42)
Percept Last	.35 (.44,.97)	.40 (.44, .92)	.69** (.44, .34)		.85*** (1.54,2.40)	.82*** (1.54,2.42)
Mixed First	.17 (.73,.97)	.31 (.73, .92)	.64** (.73, .34)	.60* (.73, .44)		.84*** (2.40,2.42)
Mixed Last	.11 (.54,.97)	.37 (.54, .92)	.59* (.54, .34)	.61* (.54, .44)	.78* (.54, .73)	

Note–SDs in parentheses (rows, columns)
$^*p < .05$ *$^{**}p < .01$* *$^{***}p < .001$*

tive capacities for processing information are not clearly separated. But with increasing age perceptual and cognitive capacities for processing information become more differentiated and independent of each other, as reflected by the lower correlations in Table 1 for adults than for children.

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