Cross-Category Differences in the Processing of Subordinate-Superordinate Relationships

Richard D. Sperber, Deborah Davies, Edward C. Merrill, and Charley McCauley

George Peabody College of Vanderbilt University

SPERBER, RICHARD D, DAVIES, DEBORAH, MERRILL, EDWARD C, and MCCAULEY, CHARLEY *Cross-Category Differences in the Processing of Subordinate-Superordinate Relationships* CHILD DEVELOPMENT, 1982, **53**, 1249–1253 We compared developmental changes in the processing of subordinate-superordinate relationships across 2 types of categories perceptual, which contain visually similar exemplars (e g, insects), and nonperceptual, which contain visually dissimilar exemplars (e g, toys) Second, fifth, and eleventh graders and mentally retarded adolescents performed a semantic priming task to assess the automatic activation of category-instance relationships, and a category-verification task to assess the speed with which decisions about category membership are made In the priming task, subjects named target pictures (e g, dog) preceded by either a category prime (This is an animal ') or a neutral prime We found that facilitative effects on target naming appeared at an earlier age for perceptual than for nonperceptual category primes In the verification task, subjects responded yes or no to superordinate and basic level descriptions of pictures Estimates of category-decision time decreased with age and intelligence for both types of categories, with these improvements in processing speed also occurring earlier in development for the perceptual categories The combined results suggest that knowledge about subordinate-superordinate relationships develops earlier for perceptual than for nonperceptual categories

In a recent study, Sperber, Davies, McCauley, and Wagor (Note 1) had college students rate the visual homogeneity among objects in 10 natural language categories, such as fruits, vehicles, toys, and furniture Instances from some categories (e g, fruits, vehicles) were consistently rated as being more visually similar to one another than were instances from other categories (e g, toys, furniture) Moreover, the perceptual homogeneity of categories was found to have a sizeable effect on the speed with which superordinate descriptions of pictures could be verified, with perceptual categories yielding faster response times than relatively nonperceptual categories

The perceptual-nonperceptual distinction observed by Sperber et al seemed to us to have direct implications for developmental theories concerned with the initial acquisition of semantic categories Several investigators have concluded that the "overextension" of basic level concepts by young children is based primarily on the perceptual similarities among objects (Anglin 1978, Clark 1978, Nelson, Rescorla, Gruendel, & Benedict 1978) Assuming that the generalization processes responsible for overextension are the same as those underlying the initial acquisition of superordinate concepts, it then follows that the visual homogeneity of objects in perceptual categories should allow these superordinates to be acquired more easily and, hence, earlier in development, than relatively nonperceptual categories The present experiment was designed, in part, to obtain evidence for cross-category differences in semantic processing that would be indicative of such differences in acquisition rate

Another goal of the present study was to examine intelligence-related differences in categorization processes in the context of the per-

This research was supported by grants HD00973, HD07045, and HD04510 from the National Institute of Child Health and Human Development We are grateful to the teachers, administrators, and students of Riverdale High School and Oakland High School, Murfreesboro, Tennessee, and Scales Elementary School, Brentwood, Tennessee, for their cooperation and participation The second author is now at Stockton State College and the third author at Teachers College, Columbia University A report of this research was presented at the Southeastern Conference on Human Development, Alexandria, Virginia, April 1980 Requests for reprints should be sent to Richard Sperber, Peabody Box 512, Vanderbilt University, Nashville, Tennessee 37203

[*Child Development*, 1982, **53**, 1249–1253 0009 3920/82/5305-0009$01 00]

ceptual-nonperceptual distinction In a previous study, Davies, Sperber, and McCauley (1981) found that semantic category primes facilitated naming times to pictures of common objects to the same degree for mentally retarded and nonretarded adolescents matched on chronological age However, when the same subjects were required to verify superordinate descriptions of pictures, the retarded individuals responded consistently more slowly than did the nonretarded individuals Davies et al interpreted these findings as indicating that retarded and nonretarded individuals do not differ with respect to basic semantic processes associated with the automatic activation of categorically related concepts, and that intelligence-related differences in categorization processes emerge only when subjects are required to actively retrieve and evaluate stored category information (see also Sperber, Ragain, & McCauley 1976)

Other aspects of their data led Davies et al (1981) to conclude that retarded-nonretarded differences in verification performance result from semantic processing differences that are quantitative in nature, that is, that retarded and nonretarded individuals differ only in terms of the speed with which active semantic processes can be executed However, the results of the Sperber et al (Note 1) study indicated the need to explore systematically an alternative possibility that individual differences in category-verification speed might be attributable to the use of qualitatively different verification processes Several aspects of the Sperber et al data provided convergent support for the conclusion that distinctly different verification processes can be used to verify perceptual and nonperceptual category descriptions According to Sperber et al, since objects in perceptual categories tend to be visually similar to one another, individuals can use featural information available in the pictures of these objects to instantiate directly their category membership Alternatively, since pictures of objects in nonperceptual categories tend to contain relatively few category-defining visual features, individuals must first identify these objects at their basic level and then base their category verifications on a purely semantic comparison of basic and superordinate concepts This alternate-process model is similar to at least one other model of picture verification (Smith, Balzano, & Walker 1978) in that there is one relatively fast process that involves the analysis of selected features relevant to the category and one slower process in which the object to be verified is first identified at its basic level

The notion that cross-category differences in perceptual homogeneity are associated with qualitatively different categorization processes suggested the possibility that retarded-nonretarded differences in superordinate verification may be limited to perceptual categories only Our thinking was that the less mature processors may not use the visual information inherent in pictures of objects from perceptual categories but, rather, may always employ the less efficient strategy of identifying these objects at their basic level for the purpose of category verification In the present experiment, we examined this possibility by investigating differences in the processing of perceptual and nonperceptual categories as a function of intelligence, as well as age

Method

Subjects—Participants were 20 educable retarded adolescents selected from the special educaton classes of two public high schools (mean IQ = 70, SD = 8 52, mean CA = 16 6 years, SD = 84, mean MA = 10 2 years, SD = 1 22), 20 nonretarded eleventh graders who served as an approximate CA match for the retarded subjects, 20 fifth graders who served as an approximate MA match for the retarded subjects, and 20 second graders The IQ measures for the retarded participants were taken from school records and were based on the Wechsler Intelligence Scale for Children or the Stanford Binet Nonretarded participants were assumed to have IQs within the normal range on the basis of teacher assessments

Design and procedure—As in the Davies et al (1981) study, two tasks were used a semantic priming task to assess the automatic activation of subordinate-superordinate relationships and a picture-verification task to examine the more active processing of these relationships In the priming task, which was administered first to all subjects, participants were asked to name line drawings of 36 common objects (three from each of 12 categories) as rapidly and accurately as possible Each picture was seen twice, once preceded by a superordinate prime (e g, "This is an animal"), and once by a neutral prime ("There is no clue for this") Under these conditions, semantic priming is reflected by the degree to which target objects following superordinate primes are named faster than those following neutral primes

The verification task was similar in format to the priming task, except that subjects re-

sponded yes and no to basic and superordinate descriptions of pictures (e g, "This is a dog" or "This is an animal") Estimates of category-decision time were based on superordinate-basic difference scores The difference-score methodology was used to control for potential group differences in the time required to encode a picture and execute a response (see Davies et al [1981] for a more detailed explanation of the difference-score methodology) Subjects saw each of the 36 pictures four times, once in each of the conditions resulting from the factorial combination of description type (basic, superordinate) × response type (yes, no)

In both tasks, pictures were presented in a three-channel tachistoscope, with the interval between the verbal description and the onset of the picture fixed at 750 msec To record response latencies, a voice-activated relay was interfaced with the tachistoscope and a Klockounter such that the onset of the picture started the timing cycle and the subject's verbal response stopped the cycle All subjects received both tasks (in separate sessions), with the exception of one retarded subject who was not available for the verification task

The designation of categories as perceptual or nonperceptual was based on normative data obtained with college students prior to the experiment For each of 12 natural language categories, the names of three highly typical exemplars were selected and paired in all combinations to form three object pairs per category Each of the resulting 36 pairs was then paired on a rating form with each of four standard pairs composed of exemplars from categories not used in the experiment Subjects were given the rating form and instructed to choose the pair within each comparison set that contained the more visually similar objects The 12 experimental categories were then rank ordered in terms of the frequency with which category pairs were selected over standard pairs, with the six highest ranking categories (insects, fruit, vehicles, animals, clothing, weapons) being designated as perceptual categories and the six lowest ranking categories (furniture, musical instruments, tools, vegetables, toys, sports equipment) being designated as nonperceptual categories

To ensure that subjects were familiar with all of the superordinate labels, at the beginning of the first experimental session each subject was asked to generate two exemplars from each of the twelve categories Only subjects successfully completing this task were included in the study

Results

Priming data —Naming errors in the priming task were relatively rare (3% overall) and there was no evidence of differential error rates as a function of groups, type of prime, or category type The data from the priming task are summarized in table 1, which presents the mean naming latencies in each condition (excluding error trials) and the resulting priming effects (superordinate-neutral difference scores) for each group

As can be seen in table 1, the results of the priming task were quite consistent with our initial expectations A groups × category type analysis of variance performed on the superordinate-neutral difference scores indicated that greater priming was obtained for perceptual than for nonperceptual categories, $F(1,76) = 13\ 48$, $p < 001$, and that the magnitude of the overall priming effect increased with developmental level, $F(3,76) = 2\ 97$, $p < 05$ Subsequent Newman-Keuls analysis

TABLE 1

MEAN NAMING LATENCIES AND PRIMING EFFECTS (in msec) FOR EACH GROUP AS A FUNCTION OF CATEGORY TYPE

	PERCEPTUAL CATEGORIES			NONPERCEPTUAL CATEGORIES		
GROUP	Superordinate Prime	Neutral Prime	Difference	Superordinate Prime	Neutral Prime	Difference
2d	792	800	8	815	814	−1
5th	672	704	32	707	694	−13
MR	745	781	36	782	784	2
11th	718	767	49	738	765	27

showed that, while eleventh graders exhibited significantly greater priming than did the second graders ($p < 05$), the priming effects obtained for fifth graders and retarded subjects did not differ significantly from each other or from those of the two extreme groups

The above analysis was designed to provide a direct test of group differences in the magnitude of the superordinate-neutral difference score It did not, however, permit us to determine the statistical significance of obtained priming effects We therefore conducted a series of t tests on the original response-time data to determine the conditions under which each group showed significant priming We found that for perceptual categories, all but the youngest group showed reliable priming effects (all p's < 05) For nonperceptual categories, only the eleventh graders showed significant priming

The implication from these results is that knowledge about natural language categories and their exemplars accrues at different rates for perceptual and nonperceptual categories For perceptual categories, subordinate-superordinate relationships are apparently well enough established by the fifth grade to show automatic activation effects, while it is not until much later in development that such effects are observed for nonperceptual categories

Verification data —The results of the verification task are presented in table 2 Error rates were again low, averaging 4% across all conditions, and did not differ as a function of groups A groups × category type analysis of the superordinate-basic difference scores yielded significant main effects of both variables (p's < 001) However, the pattern of group differences in category-decision time (as reflected by the superordinate-basic difference) was again quite different for perceptual and nonperceptual categories, $F(3,75) = 3\ 39$, $p <$ 025 Breakdown analyses of variance and subsequent Newman-Keuls comparisons indicated that, for perceptual descriptions, all groups differed significantly from each other in category-decision time (all p's < 01), except for the retarded subjects and fifth graders who showed almost identical superordinate-basic difference scores For nonperceptual descriptions, the average category-decision time for eleventh graders was significantly faster than those of the other three groups (all p's < 01), which did not differ from each other Importantly, supplemental analyses of variance of the difference scores for each group indicated that the second graders were the only subjects who did not show significantly faster decision times for perceptual than for nonperceptual categories (all p's < 01 for the remaining groups) These findings clearly indicate that developmental changes in category-verification speed occur earlier for perceptual than for nonperceptual categories

Discussion

It seems reasonable to assume that the acquisition of category knowledge is not an all-or-none event and that significant changes in category knowledge occur subsequent to the point at which the child is first able to verify the superordinate membership of an object It is likely, for example, that there continue to be changes in the particular sets of features used to define category membership and/or the associative strength of category-instance relationships We assume in this paper that such changes in category knowledge are reflected in the speed and strength of basic categorization processes, that is, we operationally define such

TABLE 2

MEAN VERIFICATION LATENCIES AND CATEGORY-DECISION TIMES (in msec) FOR EACH GROUP AS A FUNCTION OF CATEGORY TYPE

	Perceptual Categories			Nonperceptual Categories		
Group	Superordinate Description	Basic Description	Difference	Superordinate Description	Basic Description	t Difference
2d	684	602	82	711	615	96
5th	538	498	40	594	490	96
MR	608	565	43	646	547	99
11th	537	520	17	575	508	67

knowledge changes in terms of quantitative changes in category processing

Within this framework, the present findings suggest that knowledge about subordinate-superordinate relationships develops more rapidly for perceptual than for nonperceptual categories It is not until high school that there is any indication of automatic effects resulting from the activation of a nonperceptual superordinate concept, and this developing knowledge is reflected in the efficiency with which individuals execute the active semantic processes required for nonperceptual category verification Subordinate-superordinate relationships in perceptual categories, on the other hand, seem to be well enough established to show automatic effects by fifth grade In addition, the suggestion is that this developing knowledge of perceptual categories permits fifth graders to use the visual information available in pictures to determine directly the categorical identity of objects in these categories, with this process also becoming more efficient with age

With respect to intelligence-related differences in category processing, the indication from the present data is that retarded-nonretarded differences in verification speed are related to mental age rather than IQ, throughout the present study, the retarded subjects' pattern of results was identical to that of the MA-matched fifth graders In addition, there was no evidence to support the hypothesis that intelligence-related differences in verification speed result from the use of qualitatively different verification processes, since the degree to which retarded subjects' category-decision times were longer than those of their CA-matched peers was equivalent for perceptual and nonperceptual categories

The suggestion that knowledge about perceptual and nonperceptual categories is acquired at different rates invites the speculation that the mechanisms underlying the acquisition of these two types of categories also differ Consistent with this notion, the results of a recent study by Horton and Markman (1980) suggest that category knowledge may be acquired by either extensional or intensional processes, with the ability to learn through extension preceding developmentally the ability to learn effectively through intension Thus, it may be that the acquisition of perceptually homogeneous categories occurs relatively early in development and is based primarily on fundamental cognitive processes involving the recognition of common attributes (extension), whereas the acquisition of nonperceptual categories occurs somewhat later and is based on more sophisticated processes involving the application of criterion rules that define category membership (intension)

Reference Note

1 Sperber, R D, Davies, D, McCauley, C, & Wagor, W Cross-category differences in semantic processing implications for a model of picture categorization Manuscript in preparation, 1981

References

Anglin, J M From reference to meaning *Child Development*, 1978, **49**, 969–976

Clark, E V Strategies for communicating *Child Development*, 1978, **49**, 953–959

Davies, D, Sperber, R D, & McCauley, C Intelligence-related differences in semantic processing speed *Journal of Experimental Child Psychology*, 1981, **31**, 387–402

Horton, M S, & Markman, E M Developmental differences in the acquisition of basic and superordinate categories *Child Development*, 1980, **51**, 708–719

Nelson, K, Rescorla, L, Gruendel, J, & Benedict, H Early lexicons what do they mean? *Child Development*, 1978, **49**, 960–968

Smith, E E, Balzano, G J, & Walker, J Nominal, perceptual, and semantic codes in picture categorization In J W Cotton & R L Klatzky (Eds), *Semantic factors in cognition* Hillsdale, N J Erlbaum, 1978

Sperber, R D, Ragain, R D, & McCauley, C Reassessment of category knowledge in retarded individuals *American Journal of Mental Deficiency*, 1976, **81**, 227–234