PERCEPTION AND JUDGMENT OF ABSTRACT SAME-DIFFERENT RELATIONS BY MONKEYS, APES AND CHILDREN: DO SYMBOLS MAKE EXPLICIT ONLY THAT WHICH IS IMPLICIT?

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Recent studies of conceptual capacities in primates point to a fundamental distinction between monkeys on the one hand, and apes and humans on the other (Thompson & Oden, in press). The overall pattern of results suggests that monkeys, but not apes and humans, might be best regarded as "paleo-logicans" in the sense that they form class concepts on the basis of identical predicates (i.e., shared features). Their discrimination of presumably more abstract relations commonly involves relatively simple procedural strategies mediated by associative processes likely shared by all mammals. There is no compelling evidence that monkeys can perceive relations-between-relations, let alone judge them as equivalent. Thus far, this conceptual capacity for analogical reasoning has been found only in chimpanzees and humans.

Key words: **conceptual capacity, analogical reasoning, abstract relations, apes perception, human primates perception**

Interestingly, the "analogical ape", like the child, can make its analogical knowledge explicit only if it is first acquires a language or a symbol system by which propositional representations can be encoded and manipulated (e.g., Premack, 1983; Rattermann & Gentner, 1998; Thompson & Oden. 1993, 1996; Thompson, Oden, & Boysen, 1997; Tyrrell, Stauffer and Snowman, 1991).

Language-naive chimpanzees and prelinguistic human infants perceive relations (identity or nonidentity) to be the same or different as measured by either visual gaze or object handling in preference-for-novelty tasks like 'paired-comparison' and 'habituation/ dishabituation'. Interestingly, however, only those humans and chimpanzees exposed to a regime of language or symbolic token training can judge abstract relations-between- relations as being the same or different (cf., House, Brown & Scott, 1974; Premack, 1983; Sidman, 1994; Thompson, et al., 1997). This judgmental capacity is revealed in conceptual matching-to-sample tasks. In this problem a chimpanzee or child is correct if they match a pair of shoes with a pair of apples, rather than to a paired eraser and padlock. Likewise, they are correct if they match the latter nonidentical pair with a paired cup and paperweight. The conceptual matching-to-sample task can be conceived of as a non-linguistic analogy problem involving a single abstract relationship of same or different. Prior to their exposure to language or analogous symbolic token systems both humans and chimpanzees fail to match one identity relation with another and to match one nonidentity relation with another (Oden, Thompson, & Premack, 1990; Tyrrell, Zingaro, & Minard, 1993).

These findings imply that language or symbol training does not instill propositional knowledge about abstract relations of the

type described above, but it does significantly facilitate the explicit expression of such knowledge and its breadth of construal in equivalence judgment tasks. The implication then is that experience with external symbol structures and experience using them transforms the shape of the computational spaces that must be negotiated in order to solve certain kinds of abstract problems. This finding dovetails with the independent demonstration by Clark and Thornton (1997) that standard connectionist learning by artificial intelligent systems fail in exactly the same class of tasks used with the child and chimpanzee unless the net is provided with some external guidance to simplify its representational complexity.

Despite the provision of such 'external means' via symbol training with tokens, adult macaque monkeys – unlike chimpanzee or child – fail to judge the analogical equivalence of relational stimulus pairs despite their success at matching physically identical objects. (Washburn, Thompson & Oden, 1997; ms. in preparation). Why should this be? Contrary to ape and child, adult and infant macaque monkeys tested using the same preference for novelty procedures are perceptually insensitive to abstract equivalencies of an analogical, and hence, propositional nature (Thompson & Oden in press).

These findings from comparative studies imply that words or symbolic tokens enable the representational re-coding of abstract conceptual relations making them concrete and salient. Symbols thereby significantly facilitate a child's or chimpanzee's ability to explicitly represent implicitly perceived abstract properties of their world as concrete icons. Child or chimpanzee may then use these icons to make explicit conceptual judgments about those relations which they, unlike monkeys, previously only perceived implicitly early in life.

"Words and taxonomies often exert a tyranny over thoughts. If you have neither a term nor a category for something, you may not be able to see it – no matter how largely or evidently it looms." (S. J. Gould, The NYRB Oct 9, 1997).

"The use of symbols depends upon the recognition of similarity, and not the reverse." (Karl Lashley, 1929).

In the first of the above two quotes, Steven J. Gould, the American paleontologist and essayist of natural history, proposes that if one does not have a word, symbol or category for "something" then a process as basic as perceiving that "something" will likely be impossible. An alternative hypothesis is suggested in the second quotation. The famous neuro- and physiological psychologist Karl Lashley (1929) proposed that the perception of similarity is a necessary precursor of the ability to use a symbol to denote the relation. An organism must first perceive similarity in order to apply a symbol to it.

Taken to its extreme, Gould's view suggests that words are necessary for some types of perception. This has in fact been proposed in the famous Sapir-Whorf hypothesis, which states that the grammatical structure of a language shapes its speakers' perception of the world (Sapir, 1921; Whorf, 1956). While a strong Whorfian position is rarely adhered to today, the more moderate Vygotskian view — that acquiring a language confers the ability to direct one's own mental processes and to formulate mental plans has many proponents (Vygotsky, 1986). Each of these views, however, propose a direct link between symbols and thought with the common theme being that symbols are necessary to "see" the world around you. Lashley's alternative proposal, simply put, is that an organism must first perceive the similarity in order to apply a symbol to it.

As with many such "chicken or the egg" questions, the answer is far more complex than symbol to perception or perception to symbol. Part of the complexity lies in who or what is doing the perceiving. Not all perceivers are human, nor are all perceivers fully developed adult members of their species. Thus, the interaction between perception and symbol may change in important ways based on the population of interest. Also important is what is being perceived.

Without denying either of the above theoretical approaches, we offer here a third position: Namely, symbols can be used as tools that facilitate the extracting and formulating of abstractions. In this sense, the acquisition of relational terms and systems is instrumental in the development of abstract thought (Gentner & Rattermann, 1991; see also Nelson, 1996).

In this paper we will present examples of symbols as Gould would have them: a prerequisite for the ability to make explicit judgements about relations and relational similarity. We will also present evidence, however, that is consistent with Lashley's view of symbol use: the apriori ability to implicitly perceive a relation is necessary in order to use a symbol to denote that relation. Finally, we will present our third view, namely, that the use of symbols makes explicit that which is implicitly perceived by the individual. This view, which takes into consideration evidence from both human and non-human primates, is based on work examining the perception and use of relations and relational similarity. Although this is not the only area in which implicit knowledge is make explicit by the use of a symbol, it is one that has been well studied across species and therefore presents a complete view of the interaction between symbols and perception. Before laying out these different views, we will first describe several commonly used tasks that test implicit and explicit relational knowledge in both human and nonhuman primates.

Implicit Tests for the Perception of Identity

The implicit perceptual capacities of both prelinguistic human and nonhuman primates typically are inferred from tests of that to which they spontaneously attend without having to make an explicit instrumentally governed judgment response. Tests that measure the implicit perception of Identity often take advantage of a well-documented preference for novelty exhibited by both human and non-human primates. (Harris, 1943; Sokolov, 1963). The paired-comparison and habituation/dishabituation tasks that utilize this preference are widely in studies of perception and cognitive development in humans and nonhuman primates (e.g., Fagan, 1970; Fagan & Singer, 1983; Gunderson & Sackett, 1984; Gunderson & Swartz, 1986, Swartz, 1983). For example, in the paired comparison task, subjects are first given the opportunity to gaze at – or handle a stimulus object or display through out the trial of a fixed duration. Typically, cumulative stimulus handling time – or visual fixation on the stimulus is recorded as the primary dependent variable. A second test trial occurs after this initial familiarization trial. On the second trial, also of fixed duration, the now familiar stimulus is presented simultaneously with a novel stimulus and the experimenters record the cumulative attention (i.e., gaze or handling time) paid to each stimulus throughout this second comparison trial. One the one hand, if the relative attention paid to each stimulus does not differ significantly then one has no evidence that the subject spontaneously perceived the stimuli to differ. On the other hand, however, if the relative attention paid to one stimulus – typically the novel stimulus – differs significantly from that paid to the other then experimenters infer that the subject did in fact implicitly perceive the two stimuli as being different.

In the paired comparison task described above the experimenter controls the total time available to the subject for exploring the properties of the stimuli presented on both the initial familiarization and subsequent test trials. Another example of an implicit test that puts the subject in control of overall stimulus exposure time is the habituation/ dishabituation procedure. Typically in this procedure, an animal or child is first presented during the habituation phase with an object or stimulus display repeatedly over successive trials until the recorded dependent measure of handling time or gaze habituates. That is, over two consecutive trials it falls to 50% or less of that recorded on the initial two trials. In the experi-

mental dishabituation condition the animal or child is next presented with a novel stimulus. In the control condition, they experience the original (now habituated) stimulus yet again. Based on a well-documented preference for novelty exhibited by both human and non-human primates, we can predict that the animal or child will attend significantly longer (i.e., dishabituate) to the novel stimulus than to the familiar habituated stimulus if her or she implicitly perceived the novel object to differ from that presented during the habituation phase.

Explicit Judgments of Identity

Explicit conceptual knowledge in prelinguistic children and nonhuman primates typically is inferred from tests of their ability to transfer an instrumental discriminative response to novel stimuli that were not used during acquisition of the task. Explicit judgments of similarity and difference in comparative and developmental studies have been operationalized in a variety of ways. For example, judgments of physical or categorical identity can be investigated by presenting pairs of either identical or nonidentical items as discriminative stimuli for differential responding. In such Same/Different discriminations an animal is rewarded for making one response (e.g., approach) when faced with pairs of like items and for making an alternative response (e.g., avoid) when faced with a pair of unlike items. In some cases, an animal may even be capable of identifying the dimensions of similarity or difference (e.g., Pepperberg, 1987). An even more complex variation of a same/different discrimination is the conditional S/D discrimination task (e.g., Burdyn & Thomas, 1984). Here responses to pairs of identical items are reinforced in the presence of one conditional cue; responses to pairs of nonidentical items are reinforced in the presence of an alternative conditional cue.

Physical and categorical identity judgments based on absolute or probabilistic shared features are often studied using a nonverbal match-to-sample (MTS) task. Typically, in a MTS procedure a child or nonhuman animal is first presented with a single object or picture (the sample) and then allowed to choose from several alternative comparison stimuli. In identity MTS one is rewarded for choosing the alternative that is physically or categorically identical to (i.e., matches) the original sample item. Alternatively, in so-called oddity tasks one is rewarded for selecting the alternative that does not match the sample.

Analogical Judgments of Similarity

As noted above, similarity judgments in a MTS task can be based solely on physical identity or the degree of resemblance between categorical attributes. Tasks like MTS, however, are useful also for studying more abstract relational concepts, like causality and analogies, that cannot be based on physical or categorical similarities and differences (Halford, 1992; Oden et al., 2001) Judgments of analogical similarity – a hallmark of human reasoning and intelligence (Spearman, 1923; Sternberg, 1977) – entail judgments about the equivalence of higher-order relational structures and representations that need not physically resemble one another (Gentner & Markman, 1997; Goswami, 1992; Holyoak & Thagard, 1997).

The ability to make abstract analogical same/different judgments can be revealed in a conceptual matching-to-sample task that entail the matching of relations. In this matching problem animals or children are correct if they match a pair of shoes with a pair of apples, rather than to a paired eraser and padlock. Likewise, they are correct if they match the latter nonidentical pair with a paired cup and paperweight. In this example, a subject demonstrates that it judges the within-pair "Identity" relationship exemplified by two apples as being the Same relationship exemplified by paired shoes. The animal or child similarly demonstrates that he or she judges the within-pair relationship of "Nonidentity," illustrated by the eraser and padlock, as being the Same as that shown by the nonidentical paired

cup and paperweight. Thus, the conceptual matching-to-sample task can be conceived of as a nonlinguistic analogy problem involving a single abstract relationship of same or different.

The Tyranny of Words

Recall that the strong interpretation of the above quotation from Gould proposes that if one does not have not have a word or symbolic representation for "something" then one is perceptually as well as conceptually blind to that "something". At first glance this assumption makes no sense, except through the myopic lens of a hopelessly anthropocentrically focussed viewfinder. There is overwhelming evidence from both the field and laboratory that nonlinguistic animals parse their world by features, categories, functional equivalent classes and relationships (e.g., see Cheney & Seyfarth, 1990; Thompson, 1995). However, the position espoused by Gould is more deserving of attention when one considers evidence that only those humans and chimpanzees exposed to a regime of language or symbolic token training can make analogical judgements about relations between relations. This more proscribed claim, one might argue, is more consistent with the spirit of Gould's statement (House, Brown & Scott, 1974; Premack 1978; 1983a, 1983b; Thompson, Oden & Boysen, 1997). Gillan, Premack & Woodruff (1981) further demonstrated that Sarah, a "language trained" chimpanzee (i.e., trained with discursive syntactical strings of symbols) who matched relations also succeeded in completing partially constructed analogies involving complex geometric forms and functional relationships. More recently Oden, Thompson & Premack (2001) further demonstrated that this same chimpanzee could construct analogies spontaneously from a randomized grouping of geometric elements.

One example of chimpanzees without a history of training with syntactically ordered symbols who successfully matched objects but failed to match relations was reported by Oden, Thompson & Premack (1988, 1990). In those experiments infant chimpanzees (*Pan troglodytes*) spontaneously judged objects as being the same or different following acquisition of a MTS task using only two training stimuli (Oden et al., 1988). That is, having first learned to match a lock with lock and a cup with cup, all 4 subjects spontaneously transferred their matching ability under conditions of nondifferential reward to novel items and objects that in no way resembled the lock and cup experienced during training. Hence, the matching capabilities were broadly construed from the outset. Results from the transfer tests revealed that during training the animals learned – absent any explicit "instruction" to do so – to not simply match cup with cup or lock with lock, but to put "like with like".

These same infant chimpanzees, however, failed to learn a conceptual MTS task involving pairs of objects. That is, despite extensive training, these symbol-naïve infant chimpanzees consistently failed to match one identity relation (AA) with another identity relation (BB), and to match a nonidentity relation (CD) with another (EF) (Oden, Thompson, & Premack, 1990). Note that in this example and for the remainder of this paper letters (e.g., AA & CD) are used only for expository purposes to represent the physical objects or digitized images employed as stimuli.

The disparity between the infant chimpanzees' ability to match objects, but not to match relations was consistent with prior reports that only those humans and chimpanzees exposed to a regime of language or symbolic token training can judge relations as being the same or different (House, Brown & Scott, 1974; Premack 1978; 1983a, 1983b; Thompson, Oden & Boysen, 1997). These results would seem to offer good evidence in support of Gould's position. That is, the infant chimpanzees failed the relational MTS task because they lacked a word or symbol for relational sameness. But perhaps, but rather because they were perceptually insensitive to the abstract relations instantiated by the stimulus pairs.

Results from additional experiments by Oden et al., (1990) provided a test of Lashley's (1929) alternative hypothesis. That is, perhaps the infant chimpanzees failed the relational MTS task not because they lacked a word or symbol for relational sameness, but rather because they were perceptually insensitive to the abstract relations instantiated by the stimulus pairs. Using a "familiarization/novelty" procedure Oden et al (1990) found, consistent with Lashley's suggestion, but contrary to that of Gould, that the very same infant chimpanzees who failed the relational matching task nevertheless could perceive abstract identity/ nonidentity relationships between pairs of items.

The familiarity/novelty procedure used by Oden et al. (1990) was similar to the previously described non-instrumental tasks employed in studies of perception and cognitive development in humans and nonhuman primates (Fagan, 1970; Fagan & Singer, 1983; Gunderson & Sackett, 1984; Gunderson & Swartz, 1986, Swartz, 1983). – In one experiment of the Oden et al. (1990) study, infant chimpanzees handled a pair of objects mounted together on a display board for a fixed period. The object pair reflected either the "Identity" relation (e.g., two identical shoes) or the "Nonidentity" relation (e.g., an eraser paired with a padlock). After the familiarization trial, the infants were given a new pair of physically novel play objects on trial 2. The new object pair on trial 2 instantiated either the same relation (identity or nonidentity) experienced previously during the familiarization trial, or it represented the alternative relationship. The within-pair relation across trials remained the same if an identity pair (e.g., two shoes) on the familiarization trial was followed on trial 2 by a novel identity pair (e.g., two golf balls). Likewise, the within-pair relationship across trials also was familiar (i.e., the same) if a nonidentical pair (e.g., eraser and cup) followed another nonidentical pair (e.g., hose-clamp and fork). However, if a nonidentical pair on trial 2 followed an identity pair, or an identity pair on trial 2 followed a nonidentity pair, then the within-pair relation differed across trials.

Handling time associated with the object pair experienced on trial 2 was influenced by the relation with which an animal was familiarized on trial 1. Specifically, the second object pair was handled significantly less if the within-pair relation it instantiated was the same as that associated with the first object pair. If, however, the relation changed across trials, then there was no significant difference in handling times across trials. Difference scores (Tr. 1 minus Tr. 2) derived from these data showed a statistically significant main effect of whether the relation on trial 2 was either familiar or novel. These results suggest that infant chimpanzees that spontaneously detected abstract same/different relations nevertheless were unable to use this tacit knowledge to judge relations in a relational MTS. Thus, whatever the reason for the infant chimpanzees' failure to match relations, it did not result from their inability to implicitly detect such relations.

Interestingly, the disparity between implicitly perceiving and explicitly judging relations is manifested also by humans. Earlier reports claimed that children cannot judge same/different relations before the age of about 5 years (Premack, 1983; Daehler et al., 1979) but Tyrrell, Stauffer & Snowman (1991), using a paired-comparison preference-for-novelty test, demonstrated that 7 mo. old infants spontaneously attended to relational sameness and difference. The human infants first gazed at a pair of either identical or nonidentical objects for 10 s on a familiarization trial. Subsequently, on trial 2 the infants saw two pairs of novel objects. One pair consisted of identical objects; the other pair consisted of nonidentical objects. During trial 2 the infants looked significantly longer at the object pair which instantiated the novel within-pair relation.

In a procedure similar to that used by Oden et al. (1990) Rattermann, Thompson & Palchuk (in prep) presented 12- to 18-month old infants with an object-handling

task. As with Oden, et al's subjects, these infants were allowed to handle a set of two identical (or non-identical, depending upon trial type) objects until they were habituated. The investigators then presented infants with a choice of two sets of two objects – one set was an example of the identity relation and one set was an example of non-identity. They found – similarly to the infant chimpanzees – that their human infants preferred to handle the object sets instantiating the novel relation.

A Profound Disparity

The research described above points to major between- and within- species disparities. To summarize: First, both infant chimpanzees and humans can detect relational similarity as measured in preference-for-novelty perceptual tasks, but they cannot express this tacit knowledge explicitly in judgmental tasks like MTS. This disparity raises important questions as to what are the conditions necessary for the expression of an otherwise latent capacity in adult chimpanzees. Perhaps, as Gould's would propose, they needed a symbol to instantiate the relation. As noted above, only linguistically competent humans and – chimpanzees trained with syntactically ordered symbols mastered the relational matching task. An important unanswered question, then, is whether experience with syntactically embedded symbols is the basis for the emergence of the disparity originally reported by Premack (Premack & Premack, 1972; Premack, 1976).

Thompson and Oden (1993) suggested that perhaps the aspect of language training which enables chimpanzees to express instrumentally what they otherwise only perceive is the provision of concrete tokens per se associated with abstract relations of similarity and difference. Results from a relational matching study by Thompson, Oden & Boysen, 1997) are consistent with this viewpoint. Three of the chimpanzees in this study had been trained previously on a same/different discrimination task with two tokens and multiple pairs of objects. For example, given two like items they learned to choose a heart-shaped symbol and if presented with a pair of unlike items they learned to choose a symbol consisting of a diagonal bar. The fourth chimpanzee in this relational matching task was Sarah, the "language"-trained chimpanzee studied extensively by David Premack. Sarah responded correctly on 81.2% of the relational MTS trials. Likewise, the other three chimpanzees successfully matched relations at performance levels of 91%, 81%, and 84% correct responses. These performance levels were obtained under conditions in which the symbols for same and different were absent and, under conditions of non-differential reinforcement in which a choice of either alternative, whether correct or incorrect, was rewarded. Comparable correct performance levels were obtained in a physical MTS task. Importantly, the relational matching by all four chimpanzees appeared spontaneously on the first stimulus set and on two subsequent problems involving novel object pairs.

These findings were consistent with the suggestion that the views of Gould and Lashley are not mutually exclusive. As suggested by Thompson & Oden (1993) the prior provision of concrete tokens associated with abstract relations of identity and nonidentity enabled the chimpanzees – despite the tokens physical absence in the matching task – to express instrumentally what they otherwise only implicitly perceived. If the prior experience with tokens in a relatively simple same/different task underlay the ability of these chimpanzees to match relations then it implies that the tokens were not simply conditionally associated with pairs of like and unlike objects during acquisition of the original discrimination task, but functioned instead as symbols for the more abstract relational concepts of identity and nonidentity (cf., Savage-Rumbaugh, 1986). Thompson et al (1997) argued that, "Conceptual relational matching is made possible by the chimpanzee's representational capacity to re-

encode abstract relations which are instantiated by physically disparate sample and alternative pairs, into iconically identical symbols." (Thompson et al, 1997, p. 42). As noted above the tokens were not present during the relational matching task and hence, Thompson et al, (1997) hypothesized that the stimulus pairs instantiating the identity and nonidentity relations evoked covert representations of their respective symbols permitting the animals to now explicitly judge what they otherwise only implicitly perceived.

Further support for the theoretical view comes from the data for a fifth chimpanzee in the Thompson et al. (1997) study. This individual had received neither syntactical – nor token training failed the relational MTS task (i.e., 53% correct). He did, however, match objects on the basis of physical similarity (70% correct) under conditions of differential reinforcement.

Interestingly, the same regime of token training does not enable macaque monkeys to judge the analogical equivalence of stimulus pairs (Washburn, Thompson & Oden, 1997, in prep.). "Symbol-sophisticated" monkeys were trained to choose "Circle" following an identity pair (AA—O) and to choose "Triangle" following a nonidentity pair (CD—/_\). Then they generalized this ability to novel identity (BB) and nonidentity (EF) stimulus pairs. Nevertheless, unlike chimpanzees with the same experience, the monkeys still failed to match AA with BB and CD with EF. These results indicated that the same/different tokens functioned simply as cues conditionally associated with instances of physical identity and nonidentity alone. They did not function as symbols for the relational concepts of identity and non-identity.

Why Should This Be?

Thompson & Oden (1996) demonstrated that contrary to ape and child; adult macaque monkeys appear to be perceptually insensitive to analogical equivalencies of a propositional nature. Adult rhesus macaque monkeys do not spontaneously perceive analogical or relational identity. The evidence suggesting that monkeys do not perceive relational novelty was obtained originally using a paired comparison preference for novelty procedure which was the same as that used by Tyrrell et al. (1991) – described above – to demonstrate that 7-mo-old human infants were sensitive to such relations.

In contrast to the 7-mo. human infants studied by Tyrrell et al (1991) the monkeys showed no preference for novel relations as measured by differential looking time on trial 2. The differences in absolute looking time recorded for familiar and novel relations was not statistically significant. Fifty-two percent of the total looking time recorded on trial 2 was directed at the object pair instantiating the novel relation; 48% of total looking time was directed at the familiar relation. These percentages did not differ significantly from the predicted chance level.

The same monkeys, however, showed a preference for physical novelty when tested with the same procedures (e.g., Thompson, Podos & Scherer, 1990; Hardenbergh, Neff & Orman, 1991). In all these experiments absolute looking times directed to familiar and novel objects on trial 2 differed significantly. Sixty percent of the total looking time recorded on trial 2 was directed at the physically novel objects; 40% was directed at the familiar object. These percentages differed significantly ($p < .05$; t-test) from the predicted chance level of 50%. These latter results were comparable to those reported for infant macaque monkeys (e.g., Gunderson & Swartz, 1986), although there was less variance in the data obtained from the adult monkeys. This evidence for perceptual sensitivity to physical but not abstract relational similarity has been replicated several times, and it is not affected by such factors as inter-object distance within pairs, size of stimulus pool, static versus dynamic presentation of stimuli, or absolute looking times during either familiarization or test trials (Thompson, Arlinksy & Christie, 1992).

These results strongly suggest that unlike the human and ape, the monkeys are not perceptually sensitive to abstract identity/nonidentity relations, which transcend physical features. One might argue that this disparity for the monkey subjects resulted from the use of junk objects and sensitivity to relations may have been revealed had the stimuli been drawn from other stimulus domains. Perhaps, but if so it would imply an additional constraint not demanded of either child or chimpanzee.

Results obtained from infant macaques further indicate that these results are not simply a function of age (Maninger, Gunderson, & Thompson, 1997). Like the adult macaques, 7-week-old pigtailed macaque infants, in contrast to their human counterparts, fail to recognize abstract relations on a visual paired-comparison measure. This was the first study using the familiarity-novelty paradigm in Gunderson's laboratory that showed a discontinuity in perceptual-cognitive development between macaque and human infants (Grant-Webster, Gunderson & Burbacher, 1990; Gunderson, Rose & Grant-Webster, 1990; Sackett, Gunderson & Baldwin, 1982). The infant monkeys' failure to spontaneously detect abstract same/different is consistent with the results obtained from adult and aged rhesus monkeys by Thompson and his colleagues (see above) and point, therefore, to a profound disparity in the abstract representational capacities of old-world monkeys on the one hand, and apes and humans on the other.

Thus far, this disparity holds true regardless of the task (paired-comparison & habituation/dishabituation) and hence time available for information processing, or whether visual gaze or object handling is the dependent measure (Chaudhri, Ghazi, Thompson & Oden, 1997; Thompson, 1995; Thompson & Oden, 1996; Thompson, Oden, Boyer, Coleman, & Hill, 1997). Nevertheless, regardless of the dependent measure, the same animals give every indication that they perceive objects to be the same or different based on physical properties alone.

If Lashley is correct, then the overall pattern of results from the implicit perceptual studies with macaque monkeys suggests that the circle and triangle tokens in the experiments conducted by Washburn et al (1997) could not acquire symbolic meaning as they did for chimpanzees (e.g., Thompson et al., 1997). Instead the circle and triangle token were restricted to function for the monkeys simply as choice alternatives signaled by the preceding physical equivalence judgment that 'A is A' or 'C is not D'. This interpretation of token function implies that although monkeys might learn to use tokens as conditional cues, the functional meaning of such cues would not transcend the specific stimulus dimensions trained, even though transfer to novel exemplars within that dimension might be expected.

Relations and Labels – What is the Power of Words?

As noted above prelinguistic human infants as young as 7 mo. of age (Tyrrell et al., 1991) are similar to infant chimpanzees, and unlike adult or infant monkeys, in that they too implicitly perceive abstract relations of sameness and difference. Extrapolating from the results collected from the nonhuman primates one might reason then that the human infants' capacity to explicitly judge high order relations would similarly be facilitated by explicit symbol training. Evidence supporting this prediction has been reported by Rattermann and her colleagues (Rattermann & Gentner, 1990; Rattermann, Gentner and DeLoache, in preparation).

In one such study children were presented with two configurations of objects, each arranged according to the relation of monotonic increase in size relation. Monotonic increase was operationalized as three objects in a row increasing in height from left to right, or right to left. One set of objects was designated as the child's set, the other as the experimenter's set. The child was asked to close his eyes while the experimenter hid a sticker under one of the

objects in is set, Then the child opened his eyes and watched as the experimenter placed a sticker under one of the objects in her set. The child was told that if he watched carefully he could figure out where the sticker was hidden in his set. The child was then allowed to choose one of the objects in his set. The rule was always the same: the child's sticker was hidden under whichever object was playing the same relational role in his set as the object with the sticker was in the experimenter's set (that is, the object with the same relative size and position: e.g., the largest object in both sets). If the child found the sticker on the first attempt, he was allowed to keep it. If not, he was shown where it was but was not allowed to keep it.

Within this basic task the richness/complexity of the objects (rich vs. sparse) were manipulated. Richness was manipulated by using either sparse objects, such as clay pots and blue plastic boxes, or rich objects, such as a pot of brightly colored silk flowers, a toy house, a colorful mug and a toy car. Children were presented with cross-mappings in which the object similarities suggested different correspondences than the relational mapping. Using a between-subjects design, 3- and 4-year-olds were tested in the two richness conditions.

Children found this task quite difficult; both 3- and 4-year-old children had difficulty producing relational responses and the difficulty was greater for rich stimuli (32% and 38% relational responses, respectively, neither above chance) than for sparse stimuli (54% and 62%). The results bear out the prediction that children should have trouble focusing on the matching relational structure in the face of competing object similarities. This conclusion is reinforced by the finding that children selected the identical object (rather than the object playing the same relational role) more often for the rich stimuli (42% for the 3-year-olds, 32% for the 4-year-olds) than for the sparse stimuli (23% for the 3-year-olds, 23% for the 4-year-olds).

In a further study, Rattermann and Gentner again gave children the cross-mapping task, but this time they gave them labels for the higher-order relational pattern of monotonic increase. In the previous study some children had spontaneously applied the labels "Daddy, Mommy, Baby" to the objects (see also Smith, 1989). Since these terms seemed to apply to the monotonic increase pattern, in this next study 3-year-olds were to use these labels. They were given "families" in which the largest object was labeled "Daddy", the middle, "Mommy" and the smallest, "Baby". The children received explicit training trials with labeled families of penguins and bears: e.g., the experimenter said, "This is my Daddy, this is my Mommy and this is my Baby (pointing). This is your Daddy, this is your Mommy and this is your Baby. If my sticker is under my Daddy, then your sticker is under your Daddy." Then the children were tested on the same stimuli — boxes and baskets in the sparse condition and houses, cars, etc. in the rich condition — as in the first experiment. The question in this experiment was whether the family labels would increase children's ability to appreciate the higher-order pattern by inviting them to import a familiar relational schema. If so, this should make the relational choice more salient.

The results of the labeling manipulation were quite dramatic: the performance of the 3-year-olds improved to a level comparable to that of 5-year-olds with both the sparse (89% relational responding) and rich (79% relational responding) stimuli. Comparing these results with their performance in Experiment 1 (54% and 32% correct, respectively), it is as though the children gained two years of insight!

One concern is that this impressive performance depended on maintaining an artificially high level of explicit labeling. However, in a subsequent study it was found that 3-year-olds given the label training could successfully transfer to new stimuli, which they had to arrange for themselves. Although this transfer task was conducted with no further use of labels by the experi-

menter, children who had received the label training did very well. Of the 3-year-olds who had received training, 81% reached criterion with the sparse stimuli and 50% with the rich stimuli, as compared with the control (no training) group, of which 50% reached criterion with sparse stimuli and 12% with rich stimuli. This research suggests that, symbols can be used as tools for extracting and formulating abstraction. In this sense, the acquisition of relational terms and systems is instrumental in the development of abstract thought (Gentner & Rattermann, 1991; see also Nelson, 1996).

Are Symbols the Only Way to Relational Knowledge?

The research we have reviewed here strongly implies that language or symbol training does not instill prepositional knowledge about higher order abstract relations of the type described above, but it does appear necessary for the explicit expression of such knowledge in equivalence judgment tasks. The implication then is that experience with external symbol structures and experience using them transforms the shape of the computational spaces that must be negotiated in order to solve certain kinds of abstract problems. This finding dovetails with the independent demonstration by Clark and Thornton (1997) that standard connectionist learning by artificial intelligent systems fail in exactly the same class of tasks used with the child and chimpanzee unless the net is provided with some external guidance to simplify its representational complexity.

The provision of such 'external guidance' via symbol training with tokens does not enable macaque monkeys to judge the analogical equivalence of stimulus pairs.

Are Symbols Necessary or Sufficient?

The argument thus far is that experience with symbols are necessary and sufficient for the expression of otherwise implicit abstract conceptual knowledge. But perhaps they are simply sufficient and not necessary for explicit conceptually driven judgments of equivalence. Thompson and Oden (2000) cited two brief reports of possible conceptual-relational matching in symbol-naïve chimpanzees – albeit only after literally thousands of trials in what Premack (1988) aptly labeled "dogged training" (Smith, King, Witt, & Rickel, 1975; Premack (1988). Unfortunately, the limited details available in these brief reports seriously constrain their comparative interpretation across studies. Importantly, however, the efficacy of these "dogged training" procedures was apparently limited relative to that of symbol training which in the study by Thompson et al (1997), for example, was sufficient for the chimpanzees to match relations immediately in the absence of explicit training and differential reinforcement.

Research in the Cognitive Development Laboratory at Franklin and Marshall College with children provided additional support for the view that experience with symbols is sufficient but not necessary for the acquisition of a relational matching task. In an ongoing study, Rattermann, Thompson and Lehmann are testing 18- 24-month old infant's ability to perform a relational matching to sample task, with and without token training. Human infants were first given a simple relational matching to sample task using the relations of *identity* and *non-identity* and received reinforcement regardless of their response. For three days after completing the RMTS pre-test, one group of infants was given a simple token training task in which examples of identity and non-identity were shown to the infants and they were asked to choose the appropriate token to reflect each relation. The children were given differential feedback on each trail. Another control group of infants was only allowed to play with the tokens and the examples of identity and non-identity but were not asked to choose nor given any feedback. The infants were then tested again, using the RMTS task with non-differential reinforcement. The hypothesis was that the token trained infants would

show greater improvement in the RMTS post-test than the non-token trained infants. This was not, however, what was found. The performance of both groups of infants increased, becoming significantly different from chance, but not significantly different from each other. Importantly, in the case of these children, the improvement in performance, unlike that of the chimpanzees, occurred relatively quickly as opposed to thousands of differential reinforced training trials.

Conclusions

We began this paper with two quotes, one from Gould suggesting that symbols drive awareness, and another from Lashley suggesting that symbols can only be applied where awareness already exists. We propose a middle ground; symbols (including language) are powerful tools that aid in making explicit that which was previously implicit. We have shown that infants, both human and chimpanzee, are aware of the relations of identity and non-identity, and that this implicit awareness can be made explicit by the use of symbols and tokens.

So does this mean that words and symbols are both necessary and sufficient for the acquisition of relational competence? We propose that symbols alone are certainly not sufficient. As Lashley would argue, and the data from human and chimp infants support, some species quickly show the ability to perceive relations and relational similarity. This ability forms the basis for later abilities to form relational abstractions. Without this basic ability, all the symbols in the world would not enable an individual to notice and use relations and relational similarity, as was seen in the data from the experiments by Washburn et al., (1997).

Are symbols the only tool at an animal's disposal? Evidence from human infants and primates suggests that abstraction through dogged training or simply through many exposures to a relation are also effective. The results from the children and the results of "dogged training" with chimpanzees suggest that the use of symbols may not be the only road to relational competence — instead, multiple presentations of a common relation (i.e., identity) may lead to the spontaneous abstraction of that relation. In the research with children, for example, both the token-trained and the non-token trained children interacted with examples of identity and non-identity over three different training sessions. It is possible that this experience led them to align the objects and compare the common features present. In this way, an infant could come to have explicit knowledge of identity, which he or she could then carry over to the relational-matching-to-sample task.

What then are the advantages of symbols? Thompson et al, (1997) concluded that prior symbol training with tokens reduces relational matching to a task that is functionally equivalent to physical matching (see also Thompson & Oden, 2000). As Kluver suggested in the 1930s the token or symbolic tag "objectifies" a relationship per se independently of any particular exemplar (1933/1961). These notions were reiterated recently by Andy Clark (1998, 2001) who speculated, as had Thompson et al (1997) previously, that, "Learning a set of tags and labels (which we all do when we learn a language) is...closely akin to acquiring a new perceptual modality. For like a perceptual modality it renders certain features of our world concrete and salient, and allows us to target our thoughts (and learning algorithms) on a new domain of basic objects (emphasis added)...These simple objects can then be attended to in ways that quickly reveal (emphasis added) further (otherwise hidden) patterns, as in the case of relations between relations." (Clark, 2001, p. 145).

Thus, as we proposed at the outset, the interaction between implicit and explicit, is one that indeed benefits from the use of symbols, but this relationship is less of a tyranny and more that of a catalyst for what becomes an open ended reiterative process.

REFERENCES

Clark, A., Thornton, C. (1997). Trading Spaces: Computation, representation, and the limits of uniformed learning. *Behavioral and Brain Sciences, 20,* 57-90.

House, B. J., Brown, A. L., & Scott, M. S. (1974). Children's discrimination learning based on identity or difference. In H. W. Reese (Ed.), *Advances in child development and behavior, Vol. 9,* New York: Academic.

Oden, D. L., Thompson, R. K. R., & Premack, D. (1990). Infant chimpanzees (*Pan troglodytes)* spontaneously perceive both concrete and abstract same/different relations. *Child Development, 61,* 621-631.

Premack, D. (1983). The codes of man and beast. *The Behavioral and Brain Sciences, 6,* 125-137.

Rattermann, M. J., & Gentner, D. (1998). The Effect of relational language on children's performance in an analogical mapping task. In K. Holyoak, D. Gentner and B. Kokinov (Eds.) *Advances in Analogy Research: Integration of theory and data from the cognitive, computational, and neural sciences.*

Sapir, E. (1921). *Language: An introduction to the study of speech.* New York: Harcourt, Brace & World.

Sidman, M. (1994). *Equivalence relations and behavior: A research story.* Boston, MA: Authors Cooperative Inc., Publishers.

Thompson, R. K. R., & Oden, D. L. (1993). "Language training" and its role in the expression of tacit propositional knowledge in chimpanzees (*Pan troglodytes).* In H. L. Roitblat, L. M. Herman, & P. E. Nachtigall (Eds.), *Language and communication: Comparative perspectives,* pp. 365-384. Hillsdale, N. J.: Erlbaum Associates.

Thompson, R. K. R., & Oden, D. L. (1996). A profound disparity revisited: Perception and judgment of abstract identity relations by chimpanzees, human infants, and monkeys. *Behavioral Processes, 35,* 149-161.

Thompson R. K. R. & Oden, D. L. (In press). Categorical perception & conceptual judgments by nonhuman primates: The paleological monkey and the analogical ape. *Cognitive Science,* (special issue on primate cognition; Guest editor, M. Tomasello).

Thompson, R. K. R., Oden, D. L. & Boysen, S. T. (1997). Language-naive chimpanzees (*Pan troglodytes*) judge relations between relations in a conceptual matching-to-sample task. *Journal of Experimental Psychology: Animal behavior processes, 23,* 31-43.

Tyrrell, D. J., Stauffer, L. B., & Snowman, L. G. (1991). Perception of abstract identity/ difference relationships by infants. *Infant behavior and Development, 14,* 125-129.

Tyrrell, D. J., Zingaro, M. C., & Minard, K. L. (1993). Learning & transfer of identity-difference relationships by infants. *Infant Behavior and Development, 16,* 43-52.

Vygotsky, L. (1986). *Thought and language.* (A. Kozulin, Trans.) Cambridge, MA: MIT Press. (Original work published 1934)

Washburn, D. A., Thompson, R. K. R. & Oden D. L. (1997). *Monkeys trained with same/different symbols do not match relations.* Paper presented at the 38th Annual Meeting of the Psychonomic Society. Philadelphia, PA.

Whorf, B. L. (1956). Language, mind, and reality. In J. B. Carroll (Ed.), *Language, thought and reality: Selected writings of Benjamin Lee Whorf* (pp. 246-270). Cambridge, MA: MIT Press. (Reprinted from Theosophist, January and April issues, 1942, Madras, India).

PERCEPCIJA I PROSUĐIVANJE APSTRAKTNIH ODNOSA JEDNAKOG I RAZLIČITOG U MAJMUNA, ČOVJEKOLIKIH MAJMUMA I DJECE: ČINE LI SIMBOLI EKSPLICITIM SAMO ONO ŠTO JE IMPLICITNO?

SAŽETAK

Novija istraživanja pojmovnih sposobnosti primata ukazuju na temeljnu razliku između majmuna s jedne strane te čovjekolikih majmuna i čovjeka s druge (Thomson i Oden, u tisku). U cjelini uzevši, rezultati govore da bi se majmuni, ali ne i čovjekoliki majmuni i čovjek, mogli smatrati "paleologičarima" po tome što stvaraju pojam klasa na temelju istovjetnih obilježja. Za razlikovanje apstraktnijih odnosa obično su potrebne razmjerno jednostavne proceduralne strategije koje olakšavaju asocijativni procesi što su najvjerojatnije zajednički svim sisavcima. Nema sigurnih dokaza da majmuni mogu percipirati odnose među odnosima, a kamo li ih ocijeniti istovjetnima. Dosad je ta pojmovna sposobnost analogijskog zaključivanja pronađena samo kod čimpanza i čovjeka.

Zanimljivo je da "analogijski čovjekoliki majmun", poput djeteta, svoje anlalogijsko znanje može izraziti samo ako je prvo usvojio jezik ili sustav znakova kojim se mogu enkodirati i manipulirati propozicijske reprezentacije (primjerice, Premack, 1983; Rattermann i Gentner, 1988; Thomson i Oden, 1993, 1996; Thomson, Oden i Boysen, 1997; Tyrrell, Stauffer i Snowman, 1991).

Jezično naivne čimpanze i djeca u predlingvističkoj fazi primjećuju odnose (istovjetnosti ili neistovjetnosti) kao jednake ili različite bilo da ih ocjenjuju pogledom ili manipulacijom predmeta u zadacima u kojima se prioritet daje novini, kao što su 'uspoređivanja u paru' i 'privikavanje/odvikavanje'. Međutim, zanimljivo je da oni ljudi

i čimpanze koji uče jezični sustav ili simboličke znakove mogu apstraktne odnose među odnosima procijeniti kao jednake ili različite (usporedi House, Brown i Scott, 1974; Premack 1983; Sidman, 1994; Thomson i suradnici, 1997). Ta sposobnost procjenjivanja vidljiva je u pojmovnim zadacima uparivanja s uzorkom. U tom problemu čimpanza ili dijete učinit će ispravno upari li par cipela s dvije jabuke, a ne ako ga upari s kombinacijom gumice i lokota. Slično tome, učinit će ispravno upare li ovaj neistovjetan par s kombinacijom šalice i držača za papir. Pojmovni zadatak uparivanja s uzorkom možemo smatrati nelingvističkim problemom analogije koji uključuje jedan apstraktni odnos jednakog ili različitog. Prije nego što su izloženi jezičnom sustavu ili analogijskom sustavu simboličkih znakova i ljudi i čimpanze ne uspijevaju upariti dva odnosa istovjetnosti niti dva odnosa neistovjetnosti (Oden, Thompson i Premack, 1990; Tyrrell, Zingaro i Minard, 1993).

Ovi rezultati navode na zaključak da učenje jezika ili simbola ne usađuje poznavanje apstraktnih odnosa poput gore opisanih, ali značajno olakšava otvoreno iskazivanje takvog poznavanja te snalaženje u zadacima procjenjivanja istovjetnosti. Tu se zatim nameće zaključak da iskustvo s vanjskim simboličkim strukturama te iskustvo u njihovoj primjeni zahtijeva izvjesnu prilagodbu kako bi se riješili neki apstraktni problemi. Ova se spoznaja u potpunosti poklapa s onim što su neovisno o tome pokazali Clark i Thornton (1997), a to je da uobičajeno konekcionističko učenje pomoću sustava umjetne inteligencije nije uspješno u istoj vrsti zadataka koja se primjenjuje kod djece i čimpanzi osim ako se u mrežu ne daju neke upute izvana kako bi se pojednostavnila složenost predodžbi. Usprkos upotrebi takvih 'vanjskih sredstava' preko učenja simbola pomoću znakova, odrasli makaki majmuni – za razliku od čimpanze ili djeteta – ne uspijevaju procijeniti analogijsku istovjetnost odnosa parova unatoč tome što su bili uspješni pri uparivanju fizički istovjetnih predmeta (Washburn, Thomson i Oden, 1997; rukopis u pripremi). Zašto je tome tako? Za razliku od čovjekolikog majmuna i djeteta, odrasli i mladi makaki majmuni koje se testiralo istim postupcima davanja prioriteta novome, perceptivno su neosjetljivi na apstrakne istovjetnosti analogijske, pa tako i, propozicijske prirode (Thomson i Oden, u tisku)

Ovi rezultati komparativnih istraživanja navode na zaključak da riječi i simbolički znakovi omogućuju predodžbeno rekodiranje apstraktnih pojmovnih odnosa te ih čine konkretnima i lako uočljivima. Na taj način simboli djetetu i čimpanzi omogućuju da si na eksplicitan način predoče implicitno zapažene osobine njihova svijeta kao konkretne slike. Dijete ili čimpanza potom se mogu služiti tim slikama kako bi donijeli eksplicitne pojmovne prosudbe o odnosima koje su, za razliku od majmuna, ranije percipirali samo na implicitan način.