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Towards A Comparative Psychology of Cognitive Content: Exploring Tree Preference Asymmetries In Humans, Pigeons, and Monkeys

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Abstract

Conceptual structure in humans, pigeons, and monkeys was investigated using a multidimensional scaling procedure. Pigeons and monkeys were initially trained to discriminate between stimultaneously presented tree and nontree pictorial stimuli. Preference data was collected by inserting probe trials in which the animals were forced to choose between two tree stimuli. Analogous data for human subjects was collected by having subjects rate their preferences for the same stimuli. Tree preference relationships in the different datasets were obtained using the DEDICOM procedure. These analyses revealed striking interspecies differences in conceptual structure. The analysis of human tree preferences revealed a 'whole vs. part' pattern in which stimulus preference was a function of stimulus completeness. Pigeon tree preferences were qualitatively different from human tree preferences, and also appeared to be less elaborate. In general, 'branchy' stimuli were preferred over 'leafy' stimuli, and a 'whole vs. part' pattern did not emerge. The data for monkeys also illustrated a preference for 'branchy' structures over 'leafy' structures. Individual differences between monkey preferences were also revealed, and were found to be related to performance on the initial discrimination task. Monkeys that had a well-defined tree preference pattern learned this task faster than did monkeys with a less defined structure. The results of all of the analyses demonstrated interspecies differences in tree concepts, and suggested the possibility that these may be related to different functional experiences or requirements.

A key hypothesis in cognitive science is that intelligence is the product of symbolic processing. Under this hypothesis, intelligent behaviour may best be explained by providing an account of the representational system that mediates the behaviour (e.g., Pylyshyn, 1984). This "Cognitivist" hypothesis is also beginning to be applied in the study of animal behaviour (e.g., Griffin, 1978; Roitblat, 1982). Indeed, many animal behaviour researchers now assume that nonhuman species use some form of mental representation, and many recent experiments have been concerned with determining the functional characteristics of animal representational systems (e.g., Mazmanian & Roberts, 1982; Premack, 1983; Roberts, Mazmanian, & Kraemer, 1986; Roitblat, Bever, & Terrace, 1984; Sands, Lincoln, & Wright, 1982).

Roitblat (1982) makes a distinction between the *domain* and the *content* of a representation. The domain is the class of situations in the world to which the representation applies. The content is the set of features about the represented world that can be derived from the representation. It is quite likely that different species use different contents in representing identical domains. For example, one species of animal may encode a tree as a place of shelter, while another may encode the same tree as a source of food. Thus, a major issue in a comparative psychology of conceptual structure is whether the contents of representations of various species are different, and if so, in what way.

Some recent studies have shown that multidimensional scaling (MDS) procedures may be very useful in examining the contents of animal concepts (Blough, 1985; Sands, Lincoln, & Wright, 1982). The results we report come from an experiment that extends this previous methodology in two ways. First, a paradigm was used in which the preference of one stimulus over another in terms of its being "tree-like" was measured, using a set of photographs of trees in natural settings. This preference data was obtained for human, pigeon, and monkey subjects. Thus we were able to compare tree-preference relationships among three different animal species for the same set of stimuli. Second, preference data is intrinsically asymmetric (whan A is preferred over B, B is *not* preferred over A), and therefore traditional MDS analysis procedures are not appropriate. Instead, we used the DEDICOM MDS procedure, which represents the asymmetric structure of a matrix in terms of directional geometric patterns that can easily be interpreted (e.g., Harshman, Green, Wind & Lundy, 1982). When used to analyse preference data, DEDICOM indicates which stimuli were preferred over others, as well as the extent of this preference. In interpreting such a pattern, an examination of stimulus characteristics is undertaken in an attempt to understand why particular preference relationships hold. Our aim was to examine the patterns of tree preferences obtained from the three species in order to see if there were any systematic differences in the content of the concept "tree".

Data Collection

Sixteen photographic slides of trees in natural settings were used in an initial study in which human tree preferences were measured. These photographs were of a wide variety of trees, ranging from tree parts to full, leafy trees. A variety of settings were also depicted in the stimuli. Tree preference ratings for all possible permutations of pairs of these stimuli were obtained from four human subjects by having them indicate which member of each pair was the better tree. Subjects also indicated the extent of their preference on a seven point scale, as well as the perceived similarity between members of each stimulus pair.

An initial MDS analysis of the (symmetric) similarity ratings data was used to select a nonredundant subset of twelve stimuli to use for animal testing. Four ? pigeons and four squirrel monkeys were run in the experiment. The animals were initially trained using a forced choice discrimination procedure to choose a tree from a nontree by pressing the screen on which the tree picture was projected. Animals remained in this phase of the experiment until 85% accuracy was achieved over a block of five sessions. In the next phase, novel tree-nontree pairs were inserted among the training slides, and both pigeons and monkeys were highly accurate at choosing the novel tree picture in these pairs. In the final phase of the experiment, six probe trials were inserted among the training trials on each session. These probe trials consisted of pairs of tree stimuli selected from the twelve stimuli we wished to examine. Thus, the animal was forced to make a tree-preference choice between members of pairs of these critical stimuli. This procedure continued until all possible permutations of pairs of stimuli had been presented twice.

Analysis of the Human Data

The human tree preference data was averaged across the four subjects, and DEDICOM was applied to this average matrix. Two preference patterns that accounted for 69% of the variance in the data were recovered, and are presented in Figure 1. In this figure, the open circle represents the origin of the preference pattern, and stimulus objects falling near this origin are *not* strongly involved in the pattern. The arrows indicate the direction of preference in the pattern; a stimulus object at the tail of an arrow is preferred over stimuli pointed to by the head of the arrow.

The first human tree preference pattern indicated that leafy tree wholes were seen as more tree-like than leafy tree parts. The most preferred stimuli in the pattern were two full, leafy trees, while the least preferred stimuli were leafless tree parts. The whole vs. part pattern is apparent if one follows the axis of the pattern (solid line) in the direction of preference: the full leafy trees are encountered first, followed by flowering trees and a coloured fall tree, followed by pictures of tree parts in which some leaves are present. The second pattern indicated a similar structure in which the presence of leaves was not as important. In this second pattern, full tree structures with leaves, flowers or needles were preferred over less typical tree structures (a lone leafless tree and a stunted evergreen), which in turn were preferred over the stump and root.

Analysis of the Pigeon Data

A DEDICOM analysis of the averaged pigeon data revealed two striking differences from the results obtained in analysing the human data. First, only one preference pattern was recovered. This pattern, which accounted for ??% of the data variance, is presented in Figure 2. The second difference is noted in the interpretation of this pattern, as it was qualitatively different from either pattern in Figure 1. For instance, the fall deciduous tree, one of the more preferred stimuli for humans, was the least preferred stimulus for pigeons. Similarly, the stump that was one of the least preferred stimuli for humans was one of the more preferred stimuli for pigeons. In general, the entire preference pattern for pigeons suggested that stimuli that had a very well-defined "branchy" structure (i.e., long narrow projections not obstructed by dense masses of leaves, and distinct from the background) were selected by the pigeons as being more tree-like than stimuli that had a poorly defined branchy structure.

Analysis of the Monkey Data

The DEDICOM analyses of the monkey data were performed on the individual subjects' datasets, as preliminary investigations indicated a variety of individual differences. One of the animals demonstrated a single preference pattern quite similar to the structure observed in the pigeon data. Two of the monkeys demonstrated two preference patterns apiece. One of these patterns indicated a preference of well-defined "branchy" structures over poorly-defined "branchy" structures. The other of these patterns indicated a preference of stimuli representing solitary branches over stimuli in which several branches were evident. The final monkey demonstrated three separate preference patterns, accounting for ??% of the data variance, which are illustrated in Figure 3. The first of these patterns revealed the preference for well-defined "branchy" structures observed in the other animals. Note the outlying position of the evergreen in this pattern, suggesting that the animal was aware of some difference between this stimulus and the other stimuli that were used, which were predominately deciduous trees. The second pattern involved preferences among the subset of stimuli that were primarily leafless, indicating that the animal was sensitive to the presence or absence of leaves in the photographs. In this pattern, full solitary branching structures were preferred over more complicated branching structures. The final pattern revealed preference relations among (roughly) the subset of stimuli that possessed leaves. In this pattern, stimuli that had more leaves were preferred over stimuli that had few leaves.

In performing a DEDICOM analysis, use is made of a fit-to-dimensionality curve that plots the goodness of fit of a solution as a function of the number of directional patterns in the solution. This curve is used to choose the most appropriate solution for a dataset. This curve can be interpreted as providing an index of how well defined a directional structure is (c.f., Cattell, 1978). In general, if this curve is very steep and then flattens sharply, the structure is well defined (i.e., free of noise), while if the curve tends to have a more gentle initial slope, and does not sharply flatten, the structure is not well defined. Figure 4 illusrates the fit-to-dimensionality curve obtained for each monkey along with a curve inidicating the performance of the animal when learning the initial tree/nontree discrimination task. It is evident from this figure that the more well-defined the preference structure was, the faster did the animal learn the initial task. This suggests that performance on the initial learning task was related to the animal's ability to use a well-defined representational structure when making the discrimination.

Discussion

The major result of this study was that there were noticeable differences between species in terms of the preference patterns observed for the set of tree stimuli that were examined. While human subjects appeared to base their judgement on how complete stimuli appeared to be, both monkeys and pigeons were more sensitive to the "branchiness" of the stimuli. Individual differences between monkey tree preference patterns were also noted, suggesting that different animals used representations that were sensitive to different stimulus attributes. The monkey data also indicated that how well defined a preference pattern was (as indicated by fit-to-dimensionality curves) was related to performance on the discrimination task.

Although clear differences between species were noted, the reason why these differences were found is not as evident. It could be that in the tree/nontree discrimination task, the most reliable or salient feature of a tree is the presence of some branching structure. Thus, when confronted with two different tree photographs, the animal selects the stimulus that has the most branches. However, this is apparently not the only process involved. For example, the patterns illustrated in Figure 3 show that one monkey was also sensitive to the presence and absence of leaves, as well as the number of branching structures in a stimulus.

A more speculative account of the observed differences is in terms of the functional nature of different cognitive contents. It is possible that the preference for "branchiness" in the stimuli is related to the fact that pigeons view trees primarily as places to perch, and that monkeys view trees in terms of places to climb. Structures with well-defined branches are presumably structures that can be perched upon or climbed upon quite readily, and may therefore be encoded as "good" trees. Unfortunately, the complexity of the stimuli that we used prevents firm conclusions of this type to be drawn. However, we feel that these results indicate a fruitful approach to studying the conceptual structure in animals. The current results show that a particular variable (i.e., "branchiness") is very important in tree-preference patterns in both pigeons and monkeys. A similar study using a more controlled set of stimuli, in which "branchiness" was systematically varied, might begin to provide a more precise characterization of the encoding of the concept "tree" in these animals.

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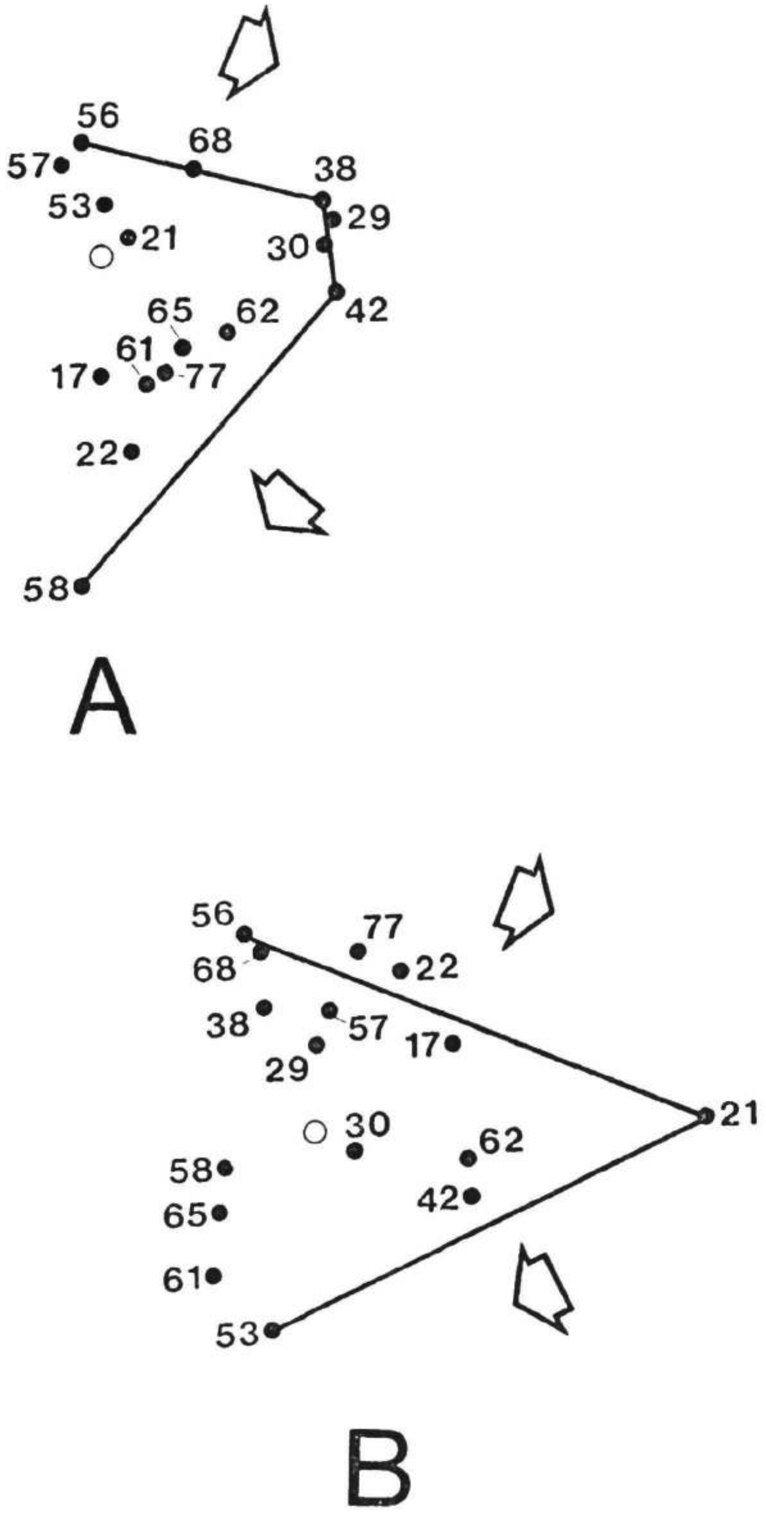
Figure 1

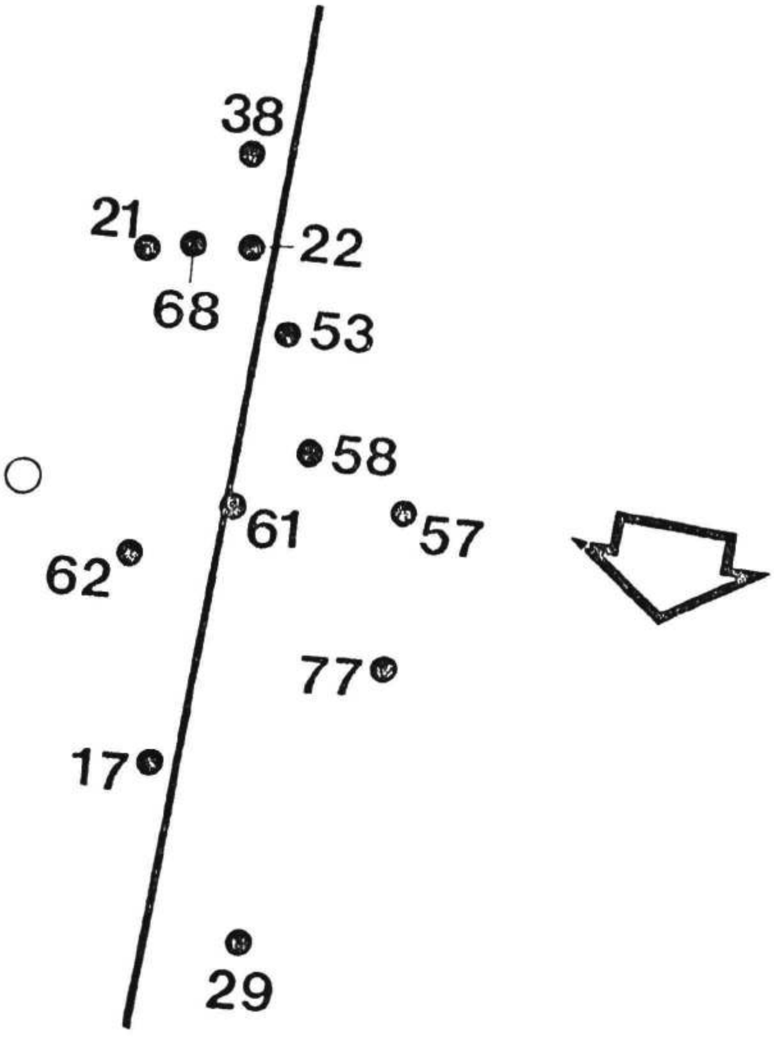
DEDICOM solutions for human tree preference data.



17 Branch with some leaves
21 Leafless deciduous tree
29 Full fall deciduous tree
30 Flowering tree
38 Flowering magnolia
42 Poor evergreen
53 Stump
56 Full deciduous tree
57 Full deciduous tree
58 Leafless branch
61 Root
62 Trees by water; not very leafy
65 Tree trunk
68 Full evergreen
77 Leafless tree by building

Figure 2

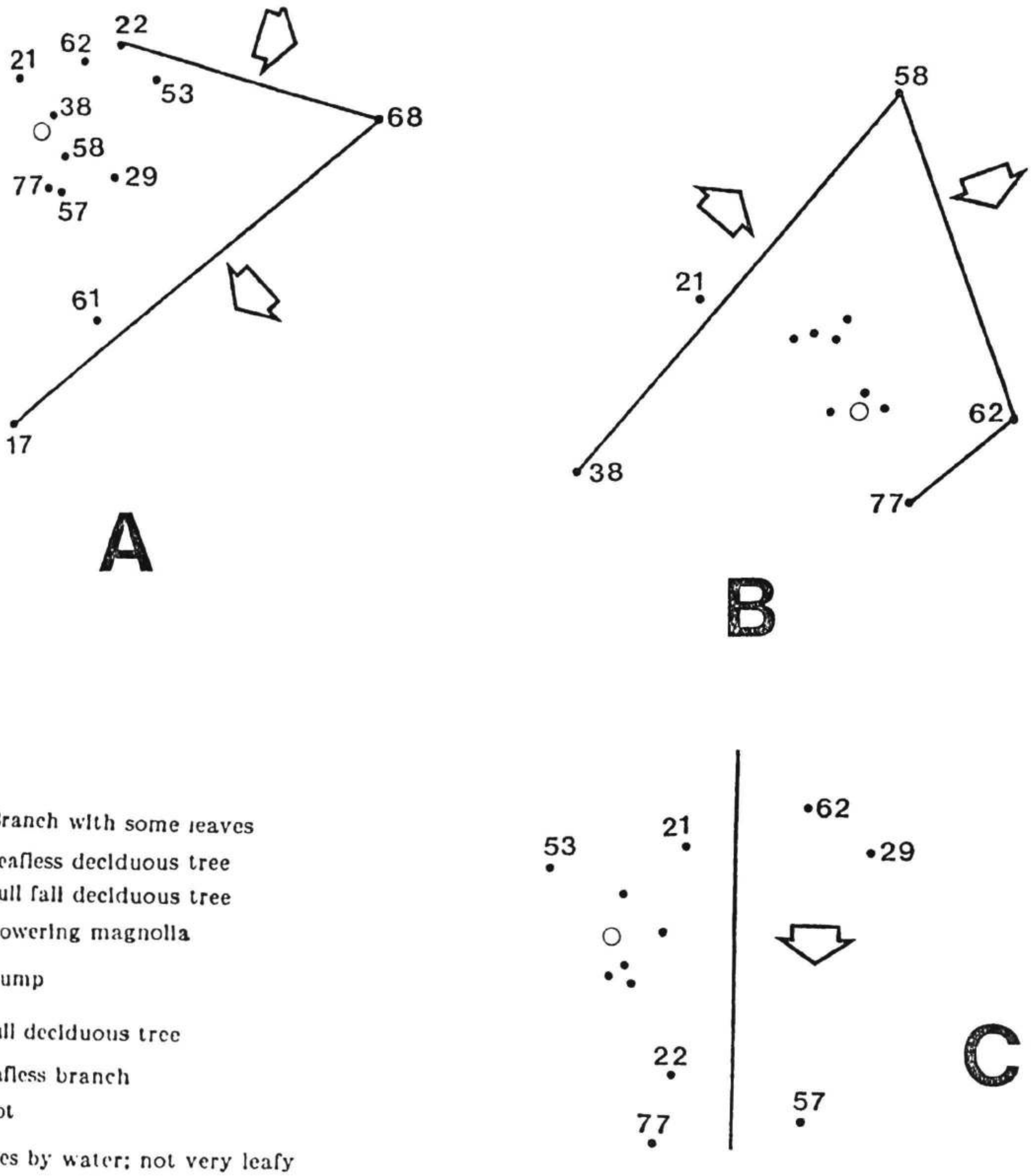
The single bimension removed from the pigeon tree preference data.



17 Branch with some leaves
21 Leafless deciduous tree
29 Full fall deciduous tree
38 Flowering magnolia
53 Stump
57 Full deciduous tree
58 Leafless branch
61 Root
62 Trees by water; not very leafy
68 Full evergreen
77 Leafless tree by building

Figure 3

Three bimensions recovered from a single monkey's tree preference data.



17 Branch with some leaves

21 Leafless deciduous tree

29 Full fall deciduous tree

38 Flowering magnolia

53 Stump

57 Full deciduous tree

58 Leafless branch

61 Root

62 Trees by water; not very leafy

68 Full evergreen

77 Leafless tree by building

Figure 4

The fit-to-dimensionality curves and the learning curves for the individual monkeys.