Can children read trees?

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Understanding the Tree of Life Conference, Carnegie Museum of Natural History (August, 2010)

Cladograms play a fundamental role in modern evolutionary biology, and are increasing in popular journals, textbooks and museums (1). Unfortunately, whilst experts find cladograms invaluable, less experienced biologists are prone to misread cladograms and draw erroneous conclusions (*2, 3*). Given the problems experienced by adults, can younger children 'tree-think'?

Method: 13 boys and 15 girls aged 7:1 to 11:11 years were trained for 15 minutes on 'fake' cladograms of magical creatures before answering eight questions on each of four new cladograms. Children were introduced to key terms before proceeding to finding common ancestors, determining relatedness, how synapomorphies (features) are inherited and the arbitrary nature of branching. Training was designed to support four types of reasoning: finding the most common recent **ancestor** of two species; identifying a species' **features** based upon its ancestry; describing which **animals** have particular features; and determining which species are most closely **related** to a particular example (simplified from *1*).

A [4 by 4 by 4 by 4] repeated measures study examined: **species** depicted in the cladogram; branch **rotation** (both counterbalanced by Greco Latin square); the **depth** of tree searched and type of **question.** Just those answers including only correct responses were considered correct (e.g. "Which animals are most closely related to the green spiny lizard?"; 'alligator and pigeon'). Analysis was by four (4 by 1) ANOVAS with post-hoc comparisons using the Bonferroni correction.

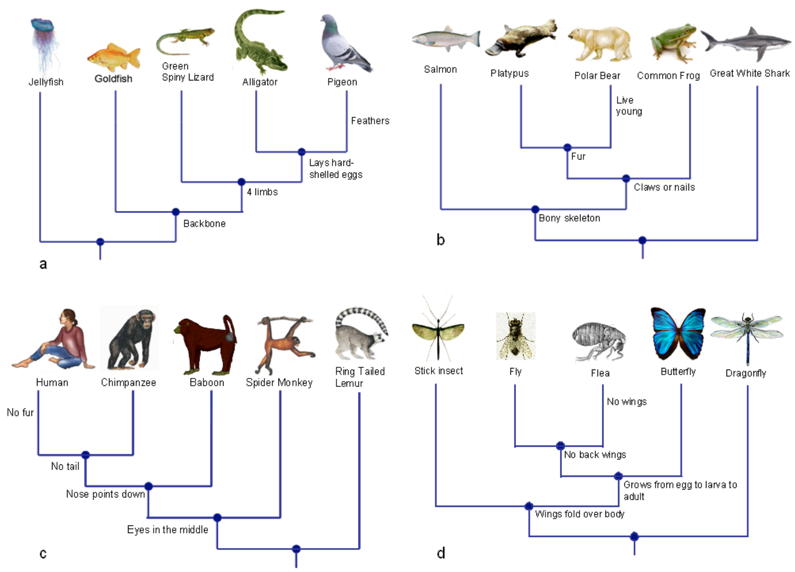

Figure 1. Cladograms with different content (indexed by rightmost species in RRRR rotation) and rotation: a) Pigeon RRRR; b) Polar Bear LRLR; c) Human LLLL; d) Flea RLRL.

Results: Children's performance was surprisingly good with an average of 56% of answers completely correct. This is significantly above chance (Ancestor: 25%, Feature/Relation: 6.67%, Animal: 3.22%).

Species represented influenced performance ($F(3,81)=9.63$, $p<0.001$). Children reasoned with flea (45%) more poorly than pigeon (63%) and human (64%) cladograms. Other researchers (*4*) have found poorer evolutionary reasoning by children about invertebrates that, in our case, cannot be explained simply by unfamiliarity (as piloting ensured these were known insects). There was no evidence of the human cladogram leading to different reasoning.

Rotation had no impact (F(3,81)=1.87). There is reasonable evidence that adults are influenced by rotation with a prevalence of RRRR style cladograms and a concomitant impact upon reasoning (*1*, *5*). Potentially, teaching children about cladograms may discourage these biases.

Children's performance worsened as the depth of tree that needed to be searched increased $F(3,81)=28.58$, $p<0.001$, $\eta 2 = .51$): Level one questions (82%) were answered more accurately than any other level (level 2 (53%) level 3 (51%) and level 4 (45%). It seems wise to recommend that cladograms for children should be relatively shallow.

Children found some types of question easier than others ($F(3,81)=10.48$, $p<0.001$, $\eta 2 = .28$). Questions about relations (39%) were answered worse than those concerning ancestors (69%) and animals (63%). Performance on the ancestor questions is particularly encouraging as it is a key skill that other tree-thinking practices build on. Analysis of verbal responses, however, suggests children answered feature and animal questions using a combination of tree-thinking and their prior (if sometimes erroneous) knowledge.

Unsurprisingly, age and number of correct answers correlated significantly ($r=.64$, $p<0.001$). The youngest quartile of children answered 39% of questions correctly and the oldest 68%.

Table 1: Correct Answers by Species, Rotation, Depth of Tree Searched and Question-Type

Species	Polar Bear	Pigeon	Human	Insect
Percentage Correct	53.13 (25.47)	63.30 (18.92)	64.29 (23.00)	44.64 (19.37)
Rotation	RRRR	RLRL	LLLL	LRLR
Percentage Correct	49.59 (25.50)	56.70 (22.69)	61.61 (19.82)	54.46 (24.82)
Depth Searched	Level 1	Level 2	Level 3	Level 4
Percentage Correct	82.14 (16.47)	53.13 (20.59`	51.34 (21.88)	45.54 (27.26)
Question-Type	Ancestor	Feature	Animal	Relation
Percentage Correct	68.75 (22.44)	54.46 (30.08)	62.95 (21.92)	39.29 (23.99)

This study suggests that after a short amount of training children can begin to reason with cladograms. This has important implications for biological communication as tree-thinking could be used with younger children than has previously been considered appropriate (our results suggest from around nine year upwards). Naturally, much of the complexity of tree-thinking will remain hard for this age group (as it is for adults) but given demonstration of this basic competency researchers can now determine how best to teach children to tree-think and to find which cladogram designs help novice tree-thinkers (6).

References

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