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1 Rats do learn XYX rules

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18 6PY

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23 rule learning

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25

26           In a study carried out with pre-linguistic infants, Marcus et al. (1999)  
27 proposed that the *XYX* sequence learning paradigm constitutes evidence of abstract  
28 rule learning related to language that is exclusive to humans. Hauser et al. (2002)  
29 found that cotton-top tamarins were also able to learn the sequence and extract a rule,  
30 extending the ability from humans to primates. Murphy et al. (2008) experiment 2  
31 showed that rats were also able to discriminate the pattern *XYX* and to transfer it to  
32 novel stimuli. Corballis' article argues against these later results and questions the  
33 involvement of this type of learning in human language.

34

35           Corballis claims that our rats -- and presumably the argument would extend to  
36 babies and cotton-top tamarins confronted with the same kind of task-- may have used  
37 a subset of stimuli to solve the rule discrimination. For instance, rats learning that  
38 *XYX* was the reinforced sequence may have matched the identity of the first and last  
39 stimulus (*X*), ignoring the interposed element (*Y*) and that this would be sufficient to  
40 discriminate *XYX* from *YYX* or *YXX*. Corballis' account is not as parsimonious as  
41 he suggests because it requires that the rat not only identify each stimulus but also its  
42 order or position in the sequence. Moreover, rats must learn which particular subset of  
43 elements are relevant among all the possible matching subsets in the sequence and  
44 finally they are required to select the precise operation to use, that is, they have to  
45 choose a "matching" operation instead of, for instance, a "higher frequency than"  
46 operation. Corballis' argument really seems to relate to which kind of rule an animal  
47 can learn or which ones might be easier rather than questioning the ability to learn  
48 rules.

49

50 Corballis acknowledges that his explanation would imply that rats in each of  
51 the three groups were behaving on the basis of different learning strategies. Thus,  
52 group XYX would have to learn the pair formed by the first and last stimuli, group  
53 XXY would have to learn the initial pair, and group YXX the final pair of stimuli in  
54 order to be able to discriminate the reinforced from the nonreinforced sequences.  
55 Learning by employing different strategies would imply different degrees of  
56 difficulty. Learning that YXX is reinforced would be expected to be quite easy  
57 because the discriminative stimulus pair is contiguous with food reinforcement,  
58 whereas learning about XXY should be more difficult given the delay between the  
59 critical stimulus pair and the reinforcement. Last, learning the reinforced sequence  
60 XYX should be particularly difficult because it would involve using the first and last  
61 stimuli as the discriminative pair. The retention interval between the two elements  
62 would retard discrimination and also this retention interval would be filled with a  
63 stimulus that would be predicted to interfere with learning. Our study did not find  
64 significant differences in the discrimination among the groups.

65

66 Corballis challenges the lack of a statistical difference by way of a  
67 hypothesized floor effect. Although always a possibility, there is no reason to believe  
68 that differential discriminative performance for the different rules (i.e., XYX, YYX or  
69 YXX) was masked by a suggested floor effect. The overall levels of responding were  
70 quite high giving more than enough room for differences to emerge and the pattern of  
71 responding did not reflect chance performance. Animals responded more during the  
72 third stimulus than at any other time during the sessions and they responded more on  
73 trials that were followed by food than on those that were not.

74

75           The rats were not required to produce any particular response to get the  
76 reinforcer, nor were they provided with a response choice. Behaviour in this  
77 procedure just shows rats anticipatory food checking and cannot be measured as  
78 reflecting a binary decision process, correct versus incorrect or go versus no-go  
79 response. We did not measure an instrumental response (goal directed) but an elicited  
80 response (a Pavlovian conditional response) as Marcus and Hauser did in their  
81 experiments in which an unconditional habituation orienting response was employed  
82 to measure discrimination. Thus, the percentage of correct responses that Corballis  
83 suggests is not only quite an unorthodox measure of Pavlovian conditioning but  
84 highly inappropriate to reflect food expectancy; in any case, the percentages obtained  
85 are not consistent with the expected degree of difficulty that Corballis' analysis  
86 entails. Furthermore, the relatively low cost of responding that this Pavlovian task  
87 imposes, together with the fact that all individual stimuli were paired with food,  
88 would be expected to elicit responses that partially interfere with the discrimination.  
89 Learning at a cognitive level is likely to be much stronger than the acquisition data  
90 suggest. This claim is supported by the extinction test data of experiment 2 that  
91 showed better discrimination than that observed at the end of training.

92

93           Configural pattern learning strategies are also ineffective in solving the  
94 discrimination. For example, configural properties such as stimulus identity (whether  
95 or not the configuration stimuli are identical) cannot be used as a discriminative cue.  
96 When applied to the last two stimuli, this property may distinguish the reinforced rule  
97 X(YX) from one of the nonreinforced rules X(YY) but not from the other  
98 nonreinforced trained rule X(XY). Similarly, rats could not have solved the

99 discrimination by configuring the first two stimuli since the nonreinforced rule (XY)Y  
100 would have been undifferentiated from the reinforced sequence (XY)X.

101

102 A third point relates to how the rats might be able to transfer learning.  
103 Corballis' favoured theory is that rats may simply 'transpose' the learned relation  
104 (Hunter 1953). It could be assumed that Corballis' preference for the use of the term  
105 transposition is due to the fact that transposition effects have been explained in terms  
106 of stimulus generalization (Spence 1937). However disappointing not being able to  
107 embrace the simpler theory might be, we cannot overlook the fact that relative or  
108 absolute transposition as described by Hunter only occurs with stimuli that are  
109 "**ordered** along a linear scale with regard to **one** feature, such as pitch or intensity"  
110 (Hunter 1953, pp. 493; emphasis added). Our stimuli (A = 3.2 KHz tone and B = 9  
111 KHz tone) were not ordered along one single dimension nor could they be linearly  
112 scaled (the sequence ABA or BAB does not follow a linear distribution along  
113 frequency). Stimulus frequencies both increased and decreased within the sequence.  
114 Change in the stimulus frequency from the training sequences to the transfer  
115 compounds therefore could not follow a transpositional monotonic relationship, such  
116 as bigger, darker, etc. Hence, animals could not discriminate or transpose on the basis  
117 of a unique orderly dimension such as the stimulus frequency. The position of the  
118 elements per se (first, second, third) was also uninformative. Discrimination could  
119 only be based on the relationship between frequency changes and the relative position  
120 in which they occurred within the sequence. The total amount of frequency change  
121 has also to be excluded as a discriminative cue. All the training sequences were  
122 formed with the same elements and hence have identical mean frequency variation.  
123 Summing up, the stimuli did not change in an orderly, linear fashion, continuously up

124 or down, with regard to one feature. The kind of stimulus relationship employed in  
125 our research is not described by Hunter. Tunes may “transpose” to a different key as  
126 Corballis suggests but this musical metaphor is just that, a metaphor. Tune  
127 transposition cannot be directly derived from Hunter’s theory.

128

129         Corballis also takes issue with details of our narrative, task and stimuli that he  
130 claims are inconsistent with aspects of human language. For instance, Corballis  
131 considers that our example of common rule use in humans, grammaticality  
132 judgements based on word order, bears no relation to our study. The example “the  
133 dog bit the woman” was introduced as illustrative of what a rule, grammatical or  
134 otherwise, is and to show that this kind of rule, as language learning does, involves  
135 constraints on the temporal ordering of events. We made no claim that rats learned  
136 linguistic categories (e.g., verb or object), grammatical rules or even that language  
137 learning is the only human cognitive domain in which temporally constrained rules  
138 are important (in fact we explicitly stated that it was not) and we certainly did not  
139 attempt to teach rats human language. We did investigate the XYX sequence learning  
140 in rats and found evidence suggesting that these animals are able to learn to  
141 discriminate this type of sequences and to transfer this knowledge to novel stimuli.  
142 The ability to transfer showed that they learn something about the structural  
143 information of the sequence and does not reflect simple stimulus generalization. We  
144 are not, however, proposing a departure from standard learning theory. We have in  
145 fact sketched elsewhere an explanation based on associative principles (Murphy et al.  
146 2009).

147

148 We did not state the complexity or language specificity of this task. Marcus  
149 and collaborators argued that XYX sequence learning in infants reveals rule learning  
150 and that this learning is required for human language (Marcus et al. 1999) and perhaps  
151 is an ability restricted to primates (Hauser et al. 2002).

152 Our experiments showed that the same rules that, despite Corballis' claims,  
153 are still reported as evidence of abstract rule learning (Marcus et al. 2007; Scott et al.  
154 2009) were also learned by rats. Whether or not such rules are accepted as being at the  
155 core of grammar learning in humans (Hauser et al. 2002) or constitute a grammar of  
156 any type, or whether the ability to generalize rules has evolved specifically for  
157 language acquisition (Hauser et al. 2002) are issues beyond the scope of our research.  
158 Nevertheless, the fact that mammals like rats can acquire rules that imply at least  
159 some level of abstraction and are considered to be involved in language learning  
160 should certainly have implications for any debate on the evolution of language and  
161 should be in accordance with an evolutionary perspective of cognition.

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## 163 REFERENCES

164

165 **Hauser, M.D., Chomsky, N. & Fitch, W.T.** 2002. The Faculty of Language: What Is  
166 It, Who Has It, and How Did It Evolve? *Science*, 298, 1569-1579.

167 **Hauser, M. D., Weiss, D. & Marcus, G.** 2002. Rule learning by cotton-top tamarins.  
168 *Cognition*, 86, B15-B22.

169 **Hunter, I. M. L.** 1953. The absolute and relative theories of transposition behaviour  
170 in rats. *Journal of Comparative and Physiological Psychology*, 45, 492-497.

171 **Marcus G.F., Fernandes K.J. & Johnson S.P.** 2007. Infant rule learning facilitated  
172 by speech. *Psychological Science*, 18, 387-391.



- 173 **Marcus, G.F., Vijayan, S., Bandi Rao, S. & Vishton, P.M.** 1999. Rule learning in  
174 7-month-old infants. *Science*, 283, 77-80.
- 175 **Murphy, R.A., Mondragón, E. & Murphy, V.A.** 2008. Rule learning by rats.  
176 *Science*, 319, 1849-1851.
- 177 **Murphy, R. A., Mondragón, E. & Murphy, V. A.** In press. Covariation, Temporal  
178 Order and Generalization: Building Blocks of Causal Cognition. *International*  
179 *Journal of Comparative Psychology*.
- 180 **Scott P. J., Fernandes, K. J., Frank, M.C., Kirkham, N., Marcus, G., Rabagliati,**  
181 **H. & Slemmer, J.A.** 2009. Abstract Rule Learning for Visual Sequences in 8-  
182 and 11-Month-Olds. *Infancy*, 14, 2–18.
- 183 **Spence, K. W.** 1937. The differential response to stimuli varying within a single  
184 dimension. *Psychological Review*, 44, 430-444.
- 185