博士論文の要旨及び審査結果の要旨

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博士論文の要旨

[Introduction] When writing an object's name, humans mentally construct its spelling1. This capacity critically depends on use of the dual-structured2 linguistic system, in which meaningful words are represented by combinations of meaningless letters. Previous studies have reported that chimpanzees (Pan troglodytes) have a similar ability to memorize and mentally construct dual-structured visual symbols representing the identity of objects3,4. To our knowledge, however, no other species have been reported to have any ability remotely resembling it. Here we challenge this view by exploring a possibility that non-hominid animals also have the ability to mentally construct the simplest dual-structured non-verbal symbols.

[Methods] We designed Yerkish and pictogram symbol systems with a dual-structure-six 'objects' are represented by six different bigrams, each of which is further constructed from two meaningless elements. Three Japanese monkeys (Macaca fuscata) were trained in three tasks. First, in the object bigram symbolization (OBS) task, the monkey was required to choose the bigram representing the object that had been presented as a visual cue. Second, in a visually-guided bigram construction (BC) task, the monkey must sequentially choose two elements constituting the bigram presented as a cue in any order they liked. Finally, we conducted a probe test using a symbolic bigram construction (SBC) task. Monkey was required to choose two elements constituting the correct bigram representing the cue object, even when the bigram itself had never been presented on the display as a hint.

[Results] Following training, the monkeys' performance was above the chance level in the OBS task (Yerkish, 90 %; pictogram, 91 %, chance level, 50 %) and in the BC task (Yerkish, 81 %; pictogram, 82 %, chance level, 17 %). In the SBC probe test, monkeys' initial-trial performance exceeded the chance level of 17 % (Yerkish, 50 %; pictogram, 56 %). The probability of successful trials

was significantly higher than predicted by the chance distribution for both Yerkish (6 out of 12 trails, binominal test, $p = 0.8 \times 10^{-2}$) and pictogram (10 out of 18 trails, $p = 1.2 \times 10^{-2}$) symbols. The data from BC and SBC task were used for voluntary choice-order analyses. First, at the initial stage of the BC task, significant choice-order bias was found for only 10 out of the 24 paired elements, the probability of which was significantly different from the chance distribution (Chi-square test for goodness of fit with Bonferroni correction). However, significant choice-order bias was found for 19/24, 19/24, and 18/24 pairs in the plateau phase of the BC task and the initial and plateau phases of the SBC task, respectively. Second, we compared the choice-order bias across task phases. The choice-order bias in the plateau phase of the BC task was stronger than in the initial phase ($\chi 2(1, 720) = 70$, $p = 3.0 \times 10^{-16}$). But the choice order bias was not significantly different between the plateau phase of the BC task and the initial phase of the SBC task ($\chi 2(1, 720) = 0.41$, $p = 2.6$). Third, we quantified the choice order bias by using a preference index. For all the monkeys/conditions, the preference index was lower in the initial phase of the BC task (0.37 ± 0.11) compared to the BC task plateau phases (0.74 ± 0.076; d.f. = 23, $t = -3.9$, $p = 3.7 \times 10^{-3}$, two-tailed t-test with Bonferroni correction) and the SBC test phase (SBC initial, 0.76 ± 0.059; d.f. = 23, $t = -0.51$, $p = 3.1$). No significant difference was found between the BC plateau phase and the SBC test phase.

[Discussion] In the present study we have shown use of dual-structured symbols by Japanese macaque monkeys with several fundamental features of human spelling. First, the macaques learned to symbolize objects with arbitrarily assigned bigrams. Second, they learned to construct bigrams by choosing arbitrary combinations of two elements with a self-generated order. These results indicate that the macaques might acquire graphotactic and semantic knowledge of the bigrams, presumably by statistical learning. Third, the animals were able to construct the bigram that was invisible but symbolically specified by a cue object, with the same choice order bias as consolidated through the bigram construction learning. These results supported the idea that the monkeys should have imagined in mind the bigram symbolically associated with the cue object and constructed the imagined bigram by mentally combining their elements. This implies that the macaques have the ability to mentally construct dual-structured symbols by integrating semantic and orthographic knowledge of the bigram.

[Conclusion] Learning of dual-structured symbols by the macaques possibly indicate pre-linguistic adaptations for the ability of mentally constructing symbols in the common ancestors of humans and Old World monkeys.

[References]

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審査結果の要旨

ヒトはモノを見てその名前を無意味な文字の組合わせとして綴ることができる。このように無意味要素か

ら意味を表す記号を組み立てる能力の進化の起源は不明であった。

申請者は、旧世界サルであるマカクザルに無意味な要素記号の組合せとしてモノを表す学習ができるかを行動学的に検証した。まず、無意味な要素記号の異なる組合せが異なるモノを表す文字様の複合記号体系を開発し、モノを見て対応する複合記号を選択する課題と、提示した複合記号を二つの要素に分解する単語分解課題をサルに行わせたところ、どちらの課題も高い成績で遂行できた。即ち、サルはモノと複合記号とを対応させる能力、複合記号の内容を理解（分解）する能力を有することが示唆された。

次に、サルにモノを提示して、意味を表す複合記号を構成する要素記号二つを選べるかを単語想起綴り課題で検証した。その結果、サルは一試行目からモノを表す複合記号を正しく組み合わせることができた。また、単語分解課題の学習を通じてサルが固定した要素を選ぶ優先順序は、単語想起綴りテストでも保持されていた。申請者は、以上の結果を統合して考察し、記号や文字を用いない旧世界サルにおいても、無意味要素から意味を表す記号を組み立てる能力を有していると結論付けた。

このような、単語を綴るのに必要な前駆言語的な能力の一端が、ヒトと旧世界サルの共通の祖先から進化した可能性を示した点に、本研究の学位論文としての価値を認める。