G/BIO
2002
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COLOR PERCEPTION OF COLORBLIND MONKEYS

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2002

ABSTRACT

PUTI S. ANGELIKA. Color Perception of Colorblind Monkeys. Under the guidance of BAMBANG SURYOBROTO and AKICHIKA MIKAMI.

Old World primates possess three types of retinal cone photoreceptors with different spectral sensitivity to long (L), middle (M) and short (S) wavelengths of light. Genes that encode L and M are located in X chromosome, whereas that for S is in chromosome No. 7. The loss of the gene that encodes either L or M photopigment in human will cause dichromatic color vision, generally known as colorblind.

Molecular genetic analysis of more than 3000 macaque monkeys showed the existence of dichromatic genotype. The defect gene is located in the X chromosome. Males carrying this defect gene on their X chromosome would have protanope characteristic. Females carrying this defect gene on one of their X chromosomes would be heterozygous. Electroretinogram (ERG) measurement shows that the sensitivity to red light was extremely low in protanopic male monkeys compared to the normal genotype. Heterozygous carrier female has sensitivity that is intermediate between the genetic protanopes and normal monkeys.

Operant conditioning technique was used to see the color perception of crab eating monkey. Two dichromatic and two normal male monkeys were trained to do a color discrimination task with food as a reward. The task is finding a circle containing red color. Result shows that both dichromatic monkeys were unable to see red color.

ABSTRAK

PUTI S. ANGELIKA. Color Perception of Colorblind Monkeys. Dibimbing oleh BAMBANG SURYOBROTO dan AKICHIKA MIKAMI.

Primata dunia lama memiliki tiga tipe *cone photoreceptors* di retina dengan sensitivitas spektrum yang berbeda terhadap panjang gelombang panjang (L), panjang gelombang menengah (M), dan panjang gelombang pendek (S). Gen yang menyandikan L dan M terletak di kromosom X, sedangkan yang menyandikan S di kromosom 7. Hilangnya salah satu gen yang menentukan pigmen itu pada manusia akan menyebabkan penglihatan dua warna (*dichromatic color vision*) yang dikenal sebagai buta warna.

Analisis genetika molekular terhadap lebih dari 3000 ekor monyet dari genus *Macaca* menunjukkan adanya genotipe *dichromat*. Genotipe *dichromat* itu disebabkan karena gen penyandi L dan M bersatu membentuk gen hibrid R4G5. Monyet jantan yang mempunyai gen hibrid pada kromosom X-nya bersifat *protanope* (tidak sensitif terhadap warna merah). Monyet betina yang mempunyai gen hibrid pada salah satu kromosom X-nya bersifat *heterozygous*. Pengukuran elektroretinogram (ERG) menunjukkan bahwa sensitivitas terhadap cahaya merah sangat rendah pada jantan *protanope* dibanding dengan jantan normal. Sensitifitas betina *heterozygous* terhadap warna merah berada di antara sensitifitas jantan normal dan jantan *protanope*.

Teknik *operant conditioning* digunakan untuk mengetahui persepsi warna dari monyet. Dua monyet jantan butawarna dan dua monyet jantan normal dilatih melakukan tugas membedakan warna dengan makanan sebagai hadiah. Tugasnya adalah menemukan lingkaran yang mengandung warna merah. Hasilnya menunjukkan bahwa kedua monyet butawarna itu tidak dapat melihat warna merah.

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Minithesis
to obtain Bachelor's of Science
in
Department of Biology

DEPARTMENT OF BIOLOGY
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BOGOR AGRICULTURAL UNIVERSITY
BOGOR
2001

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Writer was born in Semarang on 20th of February 1979 as the second child of three from the parent, the late Medhy Chumaidi and Indah Yudhawati.

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FOREWORD

Writer made this minithesis titled: Color Perception of Colorblind Monkeys, after doing the experiment since February 2001. This experiment took place in the Laboratory of Zoology Department of Biology Faculty of Mathemathic and Science Bogor Agricultural University, Bogor.

Writer's acknowledgments are send to Dr. Bambang Suryobroto and Prof. Dr. Akichika Mikami, MD as writer's counselors; to all the laboratory assistant that has helped the writer during her work at the laboratory; to Eka, Ine, Adi, Ani, and all writer's friends for their helping hands; and also to whoever that has help writer during her whole experiment. Writer's gratitudes are for Mama, whole families, and especially for Mas Wan sayang, for all their prayers and supports so writer can finish her minithesis.

Bogor, October 2001

Puti S. Angelika

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INTRODUCTION

In Old World primates, trichromatic color vision originates from three types of retinal cone photoreceptors possessing different spectral sensitivity. Those photoreceptors are sensitive to long (L), middle (M) and short (S) wavelength of light. The gene for the S cones is located on chromosome number 7, whereas the genes for the M and L cones are located on the long arm of the X chromosome (Fox, 2002). Most defects in color vision in humans arise from the loss of the gene that encodes either L or M photopigment and causing dichromatic color vision (Onishi *et al.*, 1999). People with dichromatic color vision are known as colorblind people.

Molecular genetic analysis of more than 3000 macaque monkeys showed the existence of dichromatic genotype. The defect gene is a hybrid gene constructed by genes encoding L and M photopigment and called R4G5. This hybrid gene consist of exons 1 to 4 from gene that encode L and exons 5 and 6 from gene that encode M. R4G5 gene encode a photopigment that is insensitive to red (Onishi *et al.*, 1999). Consequently, males carrying the R4G5 gene on their X chromosome would have protanope characteristic. Females carrying the R4G5 gene on one of their X chromosomes would be heterozygous. Electroretinogram (ERG) measurement shows that the sensitivity to red light was extremely low in protanopic male monkeys compared to the normal genotype. In heterozygous female, sensitivity to red light was intermediate between the genetic protanopes and normal monkeys. Decreased sensitivity to long wavelengths was thus consistent with genetic loss of L photopigment (Hanazawa *et al.*, 2001).

Although molecular genetic and physiological analysis shows the existence of dichromatism in macaque monkeys, it is still not known what is the color perception of dichromatic monkeys.

The objective of this behavioral experiment is to know the color perception of colorblind monkeys.

This experiment took place from February to August 2001, in the Laboratory of Zoology Department of Biology Faculty of Mathemathic and Science Bogor Agricultural University, Bogor.

METHODS

This experiment was using an operant conditioning technique which refers to a process in which the frequency of occurrence of a bit of behavior is modified by the consequences of the behavior (Reynolds, 1975). Two dichromatic male monkeys (#5 and #39) and two normal male monkeys (#30 and #63) were trained to do a visual discrimination task. In the task, monkeys learned to find a circle to get a piece of food as a reward. In this basic task, different colorings and brightness formed the circle. All monkeys are able to identify the circle on that condition. After they learn the basic task, they were then tested using different colorings only.

The stimulus is a color card composed by six colors, which are 1) light brown, 2) dark brown, 3) light green, 4) middle green, 5) dark green, 6) dark yellow, in decreasing order of red. Dots of brown and yellow form a circle on green dots background. The color composition of the card is shown in table 1. Each card has a control card which consist of the background color without the circle. The stimuli used were training pattern (P100) and test patterns with different levels of difficulty. The difficulty levels can be seen in table 2. The most difficult pattern is 0E which contains red color only and the easiest pattern is 50E.

After monkeys were adapted to the new environment (the experimental cage, the tools, the experimenter, etc.), monkeys were taught to pick up food from the experimental box. The experimental box has 2 little boxes in it. The color card and its control card were placed on top of those little boxes. The little box with circled color card was filled with food, such as peanut or biscuit. The little box with control card was not filled with food. When the monkey picked the little box with circled color card in his attempt to get food, he will receive one point. When the monkey picked the little box with control card, he will receive zero point and did not get food. In all sessions, pseudorandom number was used to determine the place of the color card and 40 repetition were done for each monkey for each day.

In first training session, monkeys were taught the relationship between food as a reward with the training pattern seen on top of the box. The circle of training pattern is made of dark yellow color which will be seen by both normal and dichromatic monkeys. After monkeys succeeded in picking training pattern for more than 90% for three successive days, it is concluded that the monkey knows the relationship between the colored circle and the food as reward.

The second training session was designed to introduce monkeys to the test session that will use cards with different coloring. Firstly, training pattern was mixed with 50E pattern with composition of 90% of training pattern and 10% of 50E pattern. Then, after monkeys can pick 50E pattern for more than about 90% for three successive days, the proportion of 50E pattern was raised in stages (20, 30, 40, 50, 60, 70, 80, 90, 100%). The experiment continued to test session after monkeys can pick 50E pattern in 100% condition for more than 90% for three successive days. Correction method was used in all training session when miss was repeated up to five times for the same experiment.

In test session, 50E pattern was mixed with 25E, 12E, and 0E pattern with the composition of each pattern are 85%, 5%, 5%, and 5%.

Table 1. Color composition of pattern (Komposisi warna pattern)

Pattern		Colors					
		1	2	3	4	5	6
Training pattern (P100)	Circle						√
	Background			√			
Test pattern (0E)	Circle	√	√				
	Background			√	√	√	

Chart 2. Difficulty level of pattern (Tingkat kesukaran pattern)

Difficulty level	Colors composition	
	Training pattern (P100)	Test pattern (0E)
50E	50%	50%
25E	25%	75%
12E	12%	88%
0E	0%	100%

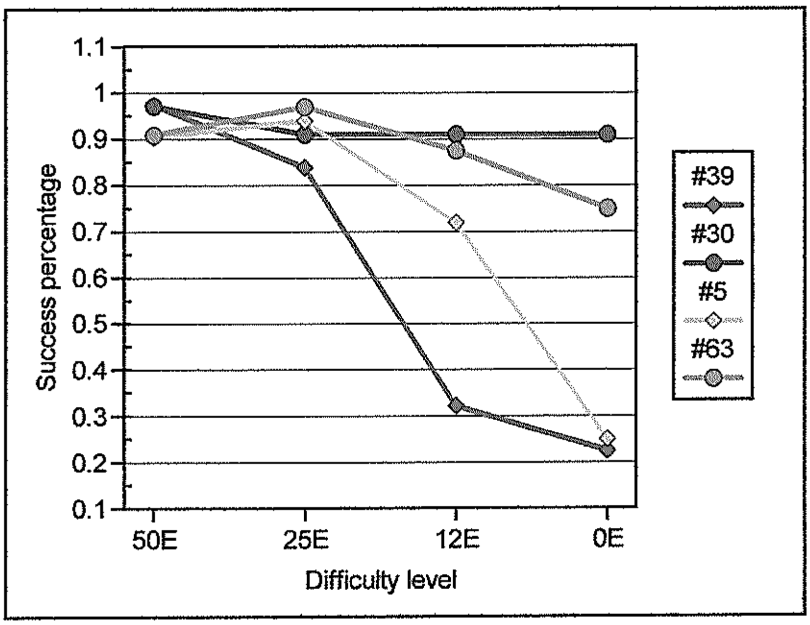

Fig 1. The monkey's success percentage in picking up pattern and get food as reward in test session
Persentase keberhasilan monyet dalam memilih pattern dan mendapatkan makanan