

# ANALYSIS OF AN EXPERIMENT ON COLOUR VISION IN DOLPHINS

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## *Summary*

Two (male/female) bottle-nosed dolphins (*Tursiops truncatus*) were trained to discriminate between two chromatic lights with changing hue and intensity. The light was projected onto a translucent frosted glass pane. A button corresponding to each colour had to be pressed. Neither animal mastered the problem. Some theoretical arguments are discussed, the methods are criticized. The data analysis shows rather sophisticated performing strategies and some indications for probability learning.

## *Introduction*

This is a short report on some experiments dealing with colour vision in two dolphins. There are many experiments on vision, visual acuity and visual discrimination in dolphins and whales (WHITE et al., 1971 a, b ; DRAL, 1974 a, b ; DRAL & DUDOK VAN HEEL, 1974 ; NOORDENBOS & BOOGH, 1974 ; HERMAN et al., 1975 ; PEPPER & SIMMONS, 1973) but we did not find any experimental work on colour vision in dolphins. Although dolphins have "retinas with predominantly rod elements" (reported in : NOORDENBOS & BOOGH, 1974 : 22) a behavioural test is lacking. When starting these experiments our interest was only to find out whether there is any evidence for the existence of colour vision. So we do not want to speculate upon evolutionary and physiological problems whether they could perceive colours or ought to be able to.

## *Subjects*

Two atlantic bottle-nosed dolphins. Both animals took part in the show. George,, male, 14 years old, captured in 1969 ; Milly, female, 17 years old, captured in 1966. In the winter of 1975/76 we carried out trials with George and James (the latter died during the experiment) to find out the most practical methods. The procedure was similar to the one described later on : The dolphin had to choose between two different 'rings' which were floating on the water surface. 274 test trials (with colour stimuli) were run with George. Then the final apparatus was designed.

## *Materials.*

The apparatus is shown in Plate 1 : A chromatic light (with use of a 500 W. bulb and Kodak Wratten filters, green and red) was projected onto a frosted glass pane (35 x 35 cm) which could be tilted. In general we used an angle of 45° which seemed to

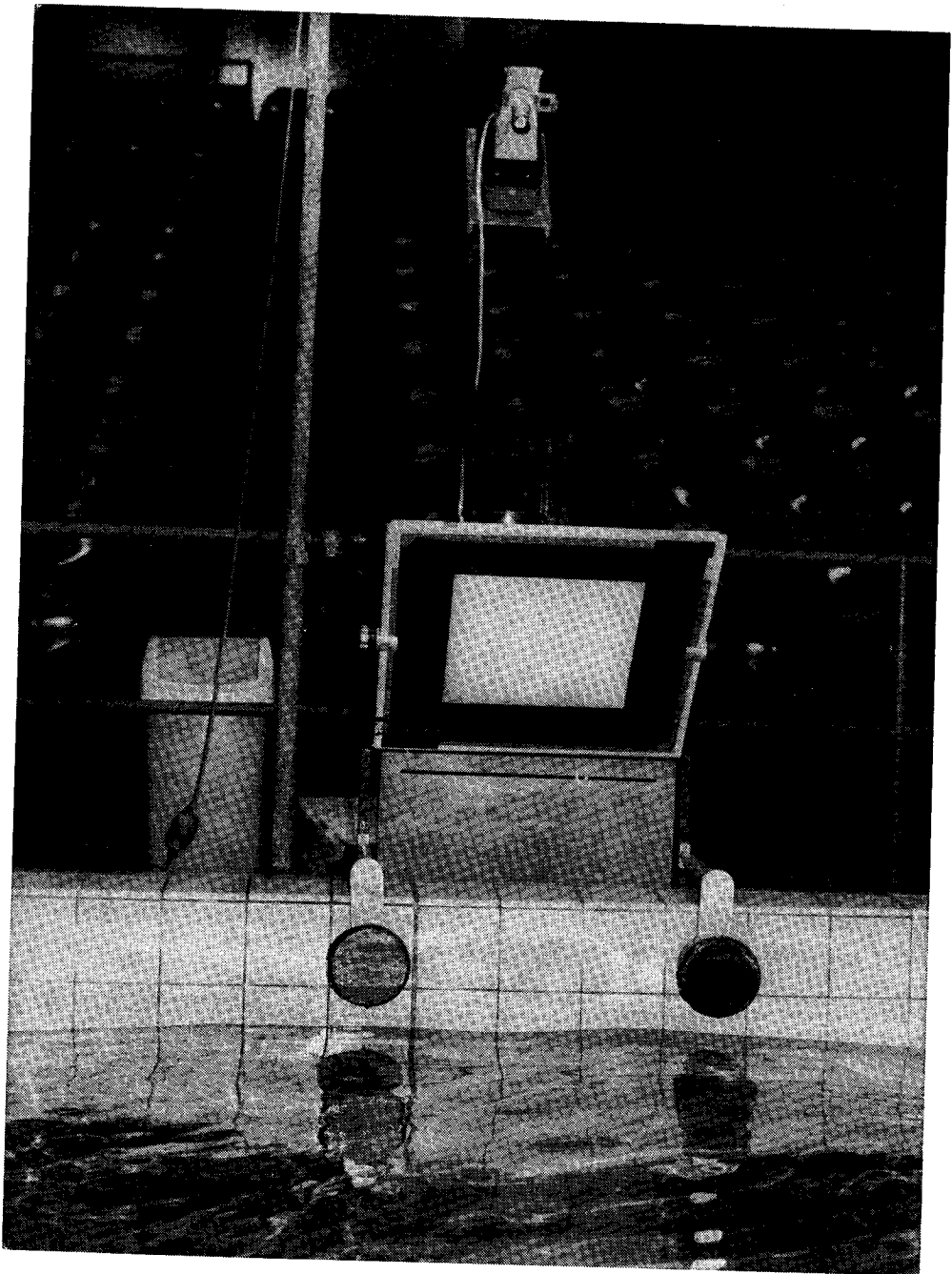


Plate 1 : Apparatus

correspond to the visual field of the dolphin. We used a flickering light with a frequency of 2 flashes per second. Just above the water surface there were two 'buttons' (15 cm diameter) which could be pressed (producing a mechanical 'click' sound). The observer knelt behind a screen (28 x 60 cm) which had a small slit (0.6 cm wide). After a few days' tests, the observer had no problem in determining which button was pressed although his eyes were closed. The whole apparatus was mobile and could be operated by one person only.

### *Methods*

After a starting sign, given from the left or right side (in random order) from the apparatus, the dolphin goes to the opposite side of the basin (distance : 9 m) where he has to press a so-called starting-button (comp. NOORDENBOS & BOOGH, 1974). When coming back to the apparatus the chromatic light is switched on. Then the dolphin presses one of the two buttons each corresponding to a given colour. Immediately after the first choice the light is turned off. This became a more and more efficient discriminative stimulus for the 'beginning of the next trial' so that pressing both buttons one after the other (= correction) could be prevented. The experiments were run in the show basin in the morning from 7 to 9 o'clock to avoid day light being brighter than the chromatic light itself. Nevertheless, forced by the continually changing light intensity of the environment and the reflection of the water colour we couldn't present a neutral stimulus but decided to test red against green. First we had selected filters (Kodak Nr. 26, 58) with nearly the same light intensity but during the last test sessions we changed hues and intensities [Kodak Nr. 40, 44, 55, 58, 65 (green) and 23A, 24, 25, 26 (red)] in order to allow the dolphins to develop brightness preferences (comp. NOORDENBOS & BOOGH, 1974). It is quite clear that for the present a different reaction to red or green could not prove anything. In general we didn't run more than 30 trials during one experimental session because of the limited quantity of food we could give to the dolphins before the shows. Sardines were used as primary reinforcer.

### *Results and discussion*

The results of our experiments neither prove nor disprove the hypothesis of colour vision in dolphins. In spite of these results we want to discuss them from a theoretical standpoint. Subsequently we will analyze the data.

Some theoretical arguments : First, it is possible for the dolphins to learn something about colours, but they do not necessarily act accordingly (learning and performance). NEUMANN & KLOPFER (1969 : 137) found a positive correlation "between the stability of a learned discrimination and increased cage size in canaries." Further examples and discussion see in : SUTHERLAND & MACKINTOSH, 1971. So the performance reveals only a more or less small part of the knowledge gained.

With regard to our method one could argue that there were too many irrelevant cues for the dolphin or that the method was too difficult in comparison to a simple discrimination task. Secondly, we have to consider the "biological boundaries of learning" which is the title of a remarkable book edited by M. E. P. SELIGMAN & HAGER (1972). There seems to be some evidence for a more or less important "unprepared-

ness" (SELIGMAN) in regard to visual stimuli (pers. comm. DUDOK VAN HEEL); the sonar is the dominant analyzer of the dolphin. A well-known example to illustrate unpreparedness: till 1973 (RESTLE, 1976) there was no successful report on avoidance learning in the pigeon by pecking a key because pecking is 'connected' with feeding and not with escape. (Further examples see in: EIBL-EIBESFELD, 1967; TINBERGEN et al., 1943; TEMBROCK, 1971). So it may be suggested that a method more corresponding to the natural behaviour of the dolphin will prove colour vision in Tursiops. Furthermore it is possible that it takes some months to overcome (=extinguish) sonar or brightness analyzers and to establish colour analyzers. It is rather safe to say, however, that both dolphins paid attention to the flickering light! Milly and George -as described above- started on their own initiative (without waiting for the starting sign) the next trial when the light was turned off. In the beginning of the experiment Milly was even afraid of the flickering light (= another reason for the failure?) which had an intensive luminous power when it was still dark outside. This behavior could be an argument for a lack of colour vision but we would not agree to that conclusion because both dolphins could have reacted to brightness cues but they did not.

### *The analysis of the data*

The following analysis will point out some interesting facts stressing the strategies of George. After nearly 500 training trials (in 24 sessions) we continued with 247 test trials. 240 times George chose the right button. This is a rather strong position preference. It is no problem to shift position habits but it is hard to avoid them in alternative tasks because of the intermittent reinforcement of basic position analyzers (SUTHERLAND & MACKINTOSH, 1971). These results correspond to a certain degree with the findings of NOORDENBOS & BOOGH (1974), that the preference for one side increases when the conflict cannot be solved. Although the reinforcement ratio is about 50% George got very frustrated when he failed (see NOORDENBOS & BOOGH, 1974). During these test trials George showed, however, VTE learning (vicarious trial and error learning; an information theory interpretation given by KLIX, 1971) with intentional movements. This behavior shows the 'effort' to get information about relevant cues!

After these unsuccessful trials we continued with the correction method: A stimulus is so often presented until a correct choice is made (= one trial; one trial may consist of several choices). This method forces the animal to look for further relevant cues. Furthermore it allows a detailed analysis of the solving strategies because strong position preferences are inhibited. So when the relevant stimulus (colour light) is not noticed four strategies can be distinguished:

1. win-stay = go to the same position/stimulus which has been reinforced before.
2. win-shift = when you were successful change position/stimulus.
3. lose-stay = when failed choose the same position/stimulus as before.
4. lose-shift = when failed change position/stimulus.

The following analysis is based on the last session, on the session before that, and on the last four sessions when George seemed to develop these strategies. However, we can only give some indications of those strategies, we cannot prove them because of the low total number of trials George made.

	trials	choices	choices		correct trials		total
			left	right	left	right	
last session	13	26	9	17	1	6	7
second last session	15	28	21	7	8	2	10
last 4 sessions	56	135	49	86	17	13	30

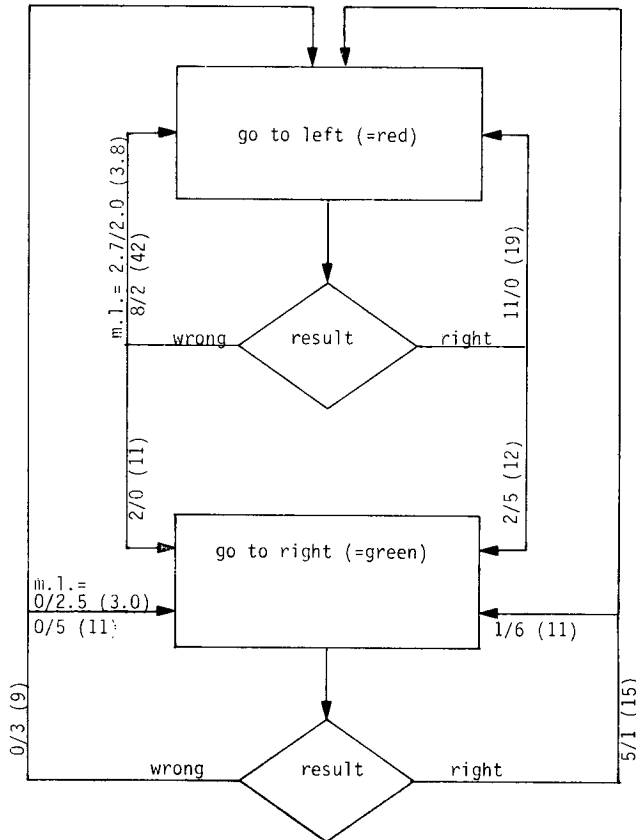


Figure 1: Win-lose strategies

Now let's look at Figure 1 which shows the different and variable frequencies of each kind of decision. The first number shows the frequencies of the last session, the second number shows those of the session before that, and the last number (put in brackets) compounds the frequencies of the last 4 sessions. M. L. means "mean loop" = the mean frequency to choose the wrong position/stimulus again. Last session: There is a general stay strategy for the left position and a partial shift strategy for the right position. George requires nearly 3 choices before giving up the wrong position/stimulus. Second last session: There is a shift strategy for the left position when correct and a lose strategy when wrong. But when the right hand position is correct George goes back to it. When the right hand position is wrong there is a

stronger tendency to go back to this position. So both positions are treated differently. The relation between shift and stay strategies when the right hand position is correct corresponds to some degree to the prediction based on the random matrix. Perhaps these results are the roots of probability learning (= matching). Last 4 sessions: The only remarkable fact is the stronger tendency to go back to the left hand position although he reacted incorrectly. There is a tendency to stay longer at the left hand position when correct rather than to shift to the right. George does not get more than about 65% correct answers because his win-shift frequency is too low (three quarters in our random matrix).

There were no distinct strategies in Milly's proceeding. She needed 318 choices in 66 trials. Her lose-stay behaviour (217) was very evident. The win-shift behaviour was equal for both positions (one third only).

It is interesting to mention that both animals seemed to make their choice long before pressing the button. Milly swam about half a metre below the water surface. 4-5 metres in front of the apparatus it could be seen where she went. George swam in a depth of about three metres in the direction of the right position . . . and pressed the left button. When swimming in a depth of about 1-2 metres in the direction of the left button he usually pressed the right button. Most of the observed 'corrections' just in front of the apparatus (= changing the button to be pressed) did fit the strategies described. Once these strategies developed at least George lost his former frustration when failing. He cooperated very well. This is obviously due to the fact that George had built up a personal probability model which allowed sufficient predictions of reinforcements.

### *Conclusions*

We could neither prove nor disprove colour vision in dolphins (*Tursiops truncatus*). It is possible that more adequate methods (simple discrimination, oddity problem!) and more adequate experimental circumstances (separated basin, constant light intensity) would bring better results. Once again it could be demonstrated that alternative tasks have a lot of problems (comp. SIMONS, 1976). Both animals built up more or less distinct strategies which prevent the dolphin to some degree learning something about the relevant cues. It is possible that the introduction of further relevant cues (e.g. brightness) can help to draw the dolphin's attention to colour cues but from a motivational standpoint we would prefer the oddity technique (comp. RESTLE, 1976). Last but not least we have found some indications for probability learning (= matching?) in dolphins.

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