TECHNIQUE OF EXPERIMENTS FOR STUDYNG ECHOLOCATION AND COMMUNICATION OF DOLPHINS UNDER THE EFFECT OF MAN-MADE INTERFERENCE

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ABSTRACT

A technique of bioacoustic experiments has been developed. The advantage of the developed method comes from the fact that two dolphins are to solve the task on detecting the object in the natural acoustic background independently on each other. However, the decision about the absence or presence of the object in the search sector the two dolphins take jointly. Using interferences of different kind, including those imitating anthropogenic ones, makes possible obtaining of adaptive acoustic characteristics of echolocation signals and plausible acoustic adaptations of communication signals. In our experiment, echolocation signals of two dolphins are separated in space by 180º. The communication signals can be unambiguously interpreted since, prior to decision making, the two animals exchange information turning their heads towards each other.

Key words: biocommunication, communication of dolphins, co-operative behavior, sonar signals, communication signals, man-made interference

1. INTRODUCTION

Ethologoacoustic observations of sea animals in the proximity of a noise source do not yield unambiguous information regarding the effect exerted by such interference on the acoustic activity of the animals. It is well known that the repertoire of the acoustic signals is much richer if the animals live in the natural habitat than in the laboratory conditions. Observations show that in the course of adaptation of the animals to captivity optimization of sonar functioning occurs resulting in the impoverishment of the acoustic palette. Laboratory data on the effect of the acoustic interference on the sonar system of sea animals are controversial. There is evidence that the acoustic interference does not make dolphins change acoustic characteristics of their signals, whereas other data suggest that the dolphins retune/readjust sonar signals depending on the acoustic environment during the experiment.

At present results of the laboratory experiments on communication between the animals as well as ethologoacoustic observations in nature do not provide any reliable evidence of the occurrence of any specified type of acoustics signals related to the purpose-directed co-operative behaviour of the animals. However, there are available data testifying to the capacity of the animals to transmit information to each other. Although no details on the methods of teaching animals elements of co-operative behaviour are given in [1, 2, 3], the statistics on their behavioural reactions provided by the authors showed that the animals find the way to the correct decision resulting in food reward offered by the researcher. The above experiments are not common because they lack any description of process of teaching co-operative behaviour in the laboratory experiment. For physiologists and biophysicists such a lack of the method of direct experiment was rather discouraging. So, ethologists were the only researchers who were involved in the study of communication behaviour of animals.

Our research aimed at the development of such a methodology of the bioacoustic experiment which would express the process of co-operative solving of the task by the animals in terms of motor activity, thus testifying to the communication and echolocation process and contributing to the unambiguous interpretation of acoustic signals as communication and echolocation signals.

An essential characteristic of the communication experiment is connected with the collective behaviour and synchronization of behavioural activity allowing the animals to foresee the actions of each other. For the animals, using the acoustic channel as the main one in detection and discrimination tasks, orientation and information exchange between the individuals abundant interference is no obstacle, whereas for the researcher signals coming from nearby animals may prove a problem very difficult to overcome. That is why in the experiment, separation of acoustic signal in time and space is necessary both during the experiment itself and the stage of signal decoding after the experiment.

2. METHODS

The developed method for co-operative behaviour of animals is based on two approaches. The first of these is described in [4, 5, 6]. It deals with the detection of under-water targets in the course of static echolocation. The dolphin and the target are immovable with respect to each other. The method proved efficient as it allowed the experimenter to obtain characteristics of the echolocation process in unfavourable acoustic conditions. Specifically, in the case of interest, the conditions for the location process change depending on the distance from the target. A particular feature of the experiment in question consists in the possibility of precise interpretation of the bioacoustic information.

Echolocation process was monitored during the experiment. The mobility behaviour in the course of the target search is closely connected with the echolocation process. For the researcher, the behavioural reaction of the animal, i.e. decision regarding the absence or presence of the target, is interpreted unambiguously (method of the imposed choice). The duration of the echolocation search is determined by the animal itself. The acoustic behaviour of the dolphin depends on the distance from the target, target's strength (its reflection characteristics) and success in solving similar tasks in the previous trials.

The scheme of the experiment on the detection of under-water targets at different distance is shown in Fig. 1. The experiment was carried out in open water. The animal was placed into a netted compartment 10×5 m. By means of a boat the target was moved, so that it could be put at a distance up to 700 m from the cage.

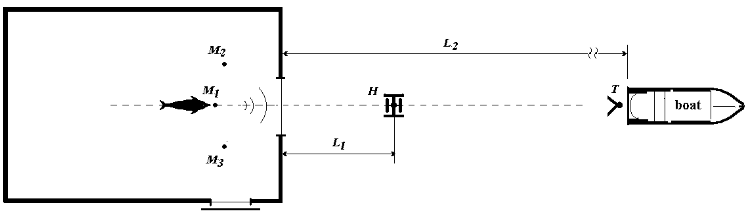

Fig. 1 Scheme of the experiment on the detection of under-water targets at different distance. M_1 – starting manipulator; M_2 – manipulator of the response reaction "there is no target"; M_3 – manipulator of the response reaction "target detected"; H – hydrophone at as distance L_1; boat at a distance L_2; T – target

Behavioural reactions of the dolphin are registered by means of its motor reactions to the manipulator. The manipulator M_1 functions both as an acoustic indicator of instructions and as the manipulator of the starting position of the animal in the cage. Following the instruction f_1 "start", the animal approaches manipulator M_1 and occupies the starting position close to the manipulator at an angle of 90º to the sector of search. Following the instruction f_2 «search», the dolphin turns towards the sector of search and begins echolocation (Fig. 1). If the dolphin decides that there is no target, it notifies the experimenter about such a decision by pressing the manipulator M_2. The animal signals about the occurrence of the target by pushing the manipulator M_3. The information about the accomplishment of the task from the experimenter comes to the dolphin via acoustic channel: signal f_3 means «correct», while signal f_4 stands for «incorrect». A broad-band system of recording was used for the registration of echolocation signals. The whole device or the hydrophone only was placed at a distance of 50 m from the cage. The time between the beginning of search and decision making is determined by the dolphin itself, the latent period depending on the complexity of the task.

The second approach contributing to the developed method suggests that the process of communication between the animals is unambiguously interpreted basing on the acoustic signaling and motor activity connected with it [8]. The developed methodology allowed us to obtain data on communication behaviour between the respondent and two observers. The methodology, used in the study of formation of learning settings up, served model for the physiological experiment. Unfulfilled action (impossibility of the animals to act), accompanied by an increasing emotional load, lies in the basis of the stimulus of the communication reaction. An inevitable acoustic interference into the work of the respondent takes place on the peak of the emotional load. The experiment was carried out on three dolphins yielding the meaningful results. They consisted in fixation of the co-operative behaviour during acoustic communication accompanied by the manifestation of motor reaction (the same for all the participants), connected with keeping watch over the respondent, i.e. turning the head or body by the animals towards each other in the course of information reception/transmission. These observations undoubtedly testify to the phenomenon of the communication behaviour. The method allowed us to unambiguously correlate the acoustic signals to the behavioural activity of the animals in the experiment. The acoustic signals are separated in time and space. The method can be reproduced in any dolphinarium. It makes possible direct decoding of the signals, thus showing possibilities of natural communication in dolphins. All the tasks accomplished within the presented methodology can be repeated and controlled even if modified and rendered more complex.

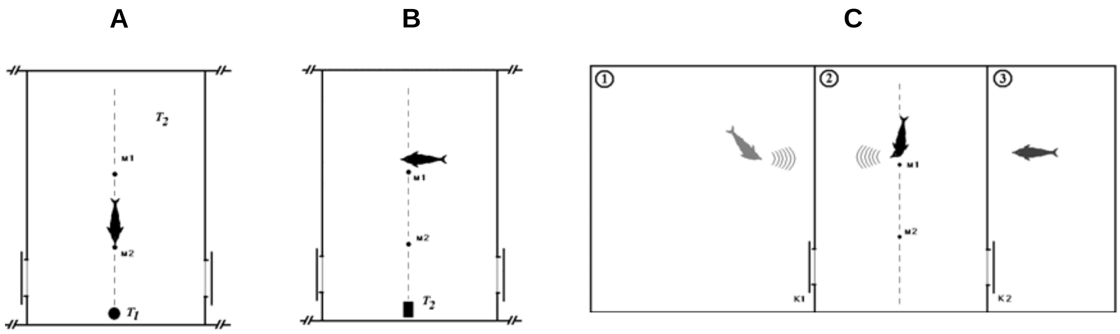

Fig.2. Motor reactions of dolphins manifested in the course of their co-operative behaviour: **A** – reaction to the target T_1; **B** – reaction to the target T_2; **C** – “dialogue” during the experiment, dolphins have their heads turned towards each other; cage 2 for the respondent and cages 1 and 3 for the observers

Fig. 2 represents the sequence of motor reactions of the dolphin accompanying the task on the discrimination of two stimuli. Motor response to the presentation of the target T_1 – from the starting position M_1 the animal pushes the manipulator M_2 (Fig.2-A). Motor response to the presentation of the target T_2 – from the starting position M1 the animal stays at the starting position and turns away from the target (Fig.2-B). The observers intervene acoustically during retuning of the discrimination reaction (Fig.2-C) accompanied by the corresponding motor reaction, i.e. turning heads towards each other. The acoustic contact, which takes place during the above motor reaction, will be called communication.

The method was modified to study the effect of the man-made interference on the process of echo sounding and communication in the open water experiment. Two animals placed in the individual movable cages took part in the experiment (fig.3.). Each animal solved its own task of target detection and discrimination following the methodology of acoustic control over motor behaviour and episodes of acoustic activity. In the experiment stimuli were presented to each animal along the geometrical axis either simultaneously or sequentially.

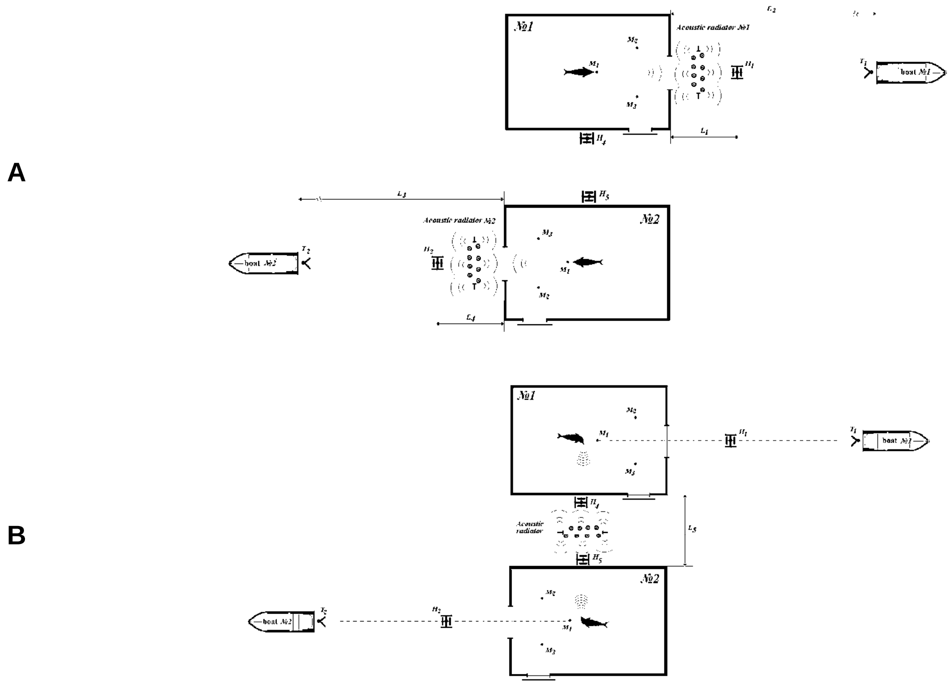

Fig.3. Scheme of the bioacoustic experiment on echolocation and acoustic communication under the conditions of anthropogenic interference: **A** – registration of echolocation signals; **B** – registration of signals in the course of communication; cage for the first dolphin №1; cage for the second dolphin №2

During accomplishment of their tasks the animals were oriented towards their own stimuli and 180° with respect to each other. The detection and discrimination task is solved by means of sonar impulses (fig.3-A), the final decision being taken only after "mutual consultations" among the participants of the experiment (fig.3-B). The researcher monitors these consultations following the motor reaction of the animals, which is manifested by turning heads towards each other in the course of communication, and acoustic reaction in communication signals. The accomplishment of the task is reported by pressing the corresponding manipulator (fig.3, M_2, M_3).

The motor reactions are accompanied acoustically without food reward. Registration of sonar signals from each animal is performed by means of hydrophones placed between the animal and target (fig.3-A, H_1, H_2). Communication signals are recorded by means of hydrophones, placed between the cages, following the direction in which dolphins turn their heads towards each other in the course of "mutual consultations" (fig.3-B, H_3, H_4). The acoustic interference is formed in the direction of the signal studied between the dolphin and target fig.3-A, Acoustic radiator №1, №2) and between two dolphins (fig.3-B, Acoustic radiator).

Acoustic signals of dolphins obtained under the conditions of man-made interference are compared to those in the natural acoustic environment. The latter is modified by the investigator depending on the task. In the experiments on echo sounding the distance between the dolphin and target varied (fig.3-A, L_2, L_3), whereas in the investigation of communication the distance between the animals placed into movable cages varied. (fig.3-B, L_5). The targets (fig.3, T_1, T_2) were changed depending on the task and at long distances were sunk from the boat (fig.3, boat №1, boat №2).

3. RESULTS AND DISCUSSION

The developed method is based on two approaches which were tested in the experiment [7, 8]. There is information available on experiments implying training of the dolphins to locate under-water targets in natural acoustic conditions under acoustic behavioural control [7]. The co-operative behaviour of the animals in the case of unfulfilled action (impossibility of physical acts of their own) is based on the acoustic intervention into the respondent's activity. Data on experiments involving imitation of anthropogenic interference during accomplishment of the task on target detection are also available in literature [9]. Thus, the basis was created for the direct experiment on communication in the course of the co-operative accomplishment of the echolocation task by dolphins.

Hydrophones for the registration of echolocation signals are arranged along the acoustic axis connecting animals with the target. The generalized reaction of the dolphin in the course of the acoustic search makes the animal keep on sounding in the specified direction even in the absence of the target, which allows one to compare location signals of search with those of detection, i.e. signals in the presence of the target. Man-made acoustic interference was imitated with a set of non-fixed transducers, the spectrum and amplitude of the interference being varied on each transducer. Varying the acoustic pressure and colour of noise (obstructing interference) one can establish the adaptive mechanisms of the echolocation behaviour of two animals.

Communication and echolocation signals are separated in time, since the "dialogue" between the individuals takes place after the process of location of the under-water target has been completed. Communication signals are registered by another set of hydrophones situated in the space between the animals. Basing on the temporal characteristics of the recording channels one can identify the participant from whom the information signal is coming. To find the most informative component of the communication signals the distance between the cages can be increased and the obstructing interference installed.

Such a large-scale experiment lasts about 2 hours. Taking into account the duration of one experiment the food reward is hardly feasible. In the experiments on the accomplishment of the echolocation task [7] the above problem was overcome. The food reward was offered before and after the experiment. In the course of 200 trials of the experiment the food reward was offered 3-4 times. The animal's response "correct or incorrect decision" is transmitted via the acoustic channel, a kind of "intermediate language" for the dolphin and experimenter. The dolphin transmits the information to the experimenter by means of motor reactions, whereas the latter uses the acoustic channel to inform the animal whether the task has been solved correctly or not.

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