LABORATORY 8

Laboratory of Sensory Information Processing

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The leading researchers of the laboratory include:

Dr.Sc. (Biol.)	D. Lapshin	Dr.	O. Orlov
Dr.Sc. (Techn.)	D. S. Lebedev	Dr.	T. Podugolnikova
Dr.Sc. (Math.)	D. G. Lebedev	Dr.	E. Rodionova
Dr.Sc. (Biol.)	I. Pigarev	Dr.	M. Smirnov
Dr.Sc. (Biol.)	G. Rozhkova	Dr.	V. Vedenina
Dr.	K. Golubtsov		P. Maximov
Dr.	E. Maksimova		D. Nikolaev
Dr.	V. Maximov		

FIELD OF RESEARCH

The main research area of the laboratory is investigation of information processing in sensory systems and in nervous system of man and animals in general. These researches are aimed onto:

- elaboration of adequate models which show how the studied principles of information processing in the nervous system are realized in the formation of complex behaviour;
- elaboration of mathematical models simulating significant functions of distinct divisions of sensory systems, including peripheral, central and sensorimotor levels of information processing;
- comparison of principles and solutions of similar problems in live and technical information systems intended to improve the later;
- designing and implementing diagnostic methods and devices for ophthalmology.

To cope with the problems mentioned, different approaches and methods are used by the laboratory researchers, including neurophysiological, psychophysical and morphological methods, as well as animal behaviour field studies and computer simulations of sensory processing. Among the most important problems is description and classification of numerous functional types of neural units which are involved in the sensory information processing at several levels of integral nervous system. Thus, in vision the peripheral level of information processing is represented by the retina, while the brain visual centres (cortex and caudate nucleus in cats and monkeys, diencephalon and mesencephalon in fish and in frogs) represent the central level. Investigation of neurons' functional types is performed by means of both neurophysiological and morphological methods. Microelectrode experiments are aimed on recordings of responses from separate single units (neurons) at different levels of the retina, which itself is composed of several distinct layered nerve structures, each of them being a complex ordered network built of different neuron classes. These experiments are performed on immobilized live animals using their visual stimulation. Morphological studies specify those neural structures and morphology of the nerve cells which are subject of neurophysiological investigation. Functional features of

neural components are the matter of comparison to some distinct forms of sensory-guided integral behaviour of the same experimental animals (fish, amphibia cats), this way providing the background for modeling of corresponding neural circuits in terms of computer simulations. Such, computer simulations include modeling of neural event underlying of information processing at the level of cone receptor population (in primate retina), as well as interaction of receptor and horizontal cells in the retina (in fish). General principles of sensimotor information processing (such as colour and size constancy in visual perception, binocular vision mechanisms, spatial orientation, echolocation in moths, bioacoustics in locusts during the breeding period) are the matter of psychophysical experiments on both healthy subjects and medical patients having different sensory disturbances; as well as in behavioural experiments on animals. Basic researches provide the background for applied outcomes in the form of diagnostic methods and devices for medical ophthalmology, which are as well being designed and implemented by the laboratory staff.

A system of classifying features was developed, the classification of direction-selective ganglion cells in retino-tectal projection of fishes was carried out and their properties were investigated. In fishes, direction-selective ganglion cells were shown to comprise six physiological types, that differ in preferred directions and in sign of preferred contrast. Unlike the terrestrial vertebrates (rabbit), whose direction-selective ganglion cells are selective to four mutually perpendicular preferred directions, the goldfish's ones are selective to three preferred directions separated by about 120°. Coincidence in number of preferred directions with number of semicircular canals implies that direction-selective ganglion cells projecting to tectum are involved in some multimodal sensory integration in postural, locomotor and oculomotor control in 3D aquatic environment. (V.V. Maximov, E.M. Maximova, P.V. Maximov, O.Yu. Orlov, I.A. Knorre)

Computer modeling was used to reveal some specific features of the central primate retina structure and to explain a possibility of some amacrine cells to generate the red-green opponent signals. A hypothetical amacrine cell network was included into the computation model of the central primate retina which had been elaborated earlier. The computer experiments yielded the responses of the model ganglion cells to various stimuli which were similar to those of the real midget ganglion cells of the central primate retina. (D.S. Lebedev)

It was suggested that various illusions determined by the same visual mechanism should demonstrate similar age dynamics and significant correlation. To test these suggestions, the illusions of two principally different classes were studied. The illusions of one class (the illusions of Hering and Mueller-Lyer and the illusion of perspective) were supposedly determined by the constancy mechanism of size perception while the illusions of the second class had no relation to this mechanism. All the illusions were estimated quantitatively in 100 children and 200 young adults. The results confirmed the suggestion concerning age dynamics but failed to confirm anticipated significant correlation between various illusions belonging to one class. To reveal the cause of this failure, in the additional series of the experiments with the computer generated test images, the parameters of the test images were varied to study the effect of these variations on the magnitude of the illusions. All the arrangement of the test images appeared to be important. It was found that such parameters as orientation, relative positions, absolute and relative sizes of the controlled and referent details influenced the results markedly. This means that, in a general case, there is no reason to expect significant correlation between the results obtained for

the test images differing greatly in configuration. (G.I. Rozhkova, V.S. Tokareva, V.A. Bastakov, V.A. Ognivov).

Neuronal responses in the caudate nucleus to the cortical electrical microstimulation were investigated during the periods of active wakefulness and in sleep. Excitatory and inhibitory responses of the caudate neurons, observed in wakefulness, were strongly reduced or disappeared completely during sleep. This effect indicated that signal propagation from the cortex to caudate nucleus is blocked during sleep. However, robust responses of the caudate neurons to cortical microstimulation were rather rare in spite of the known dense projections from the stimulated cortical areas to the basal ganglia. To confirm the block of signal propagation from the cerebral cortex to the basal ganglia, background activity of 88 neurons in the cerebral cortex and caudate nucleus was compared in wakefulness and sleep. It was shown that mean background cortical activity increased in sleep while at the same time mean neuronal firing in the caudate nucleus decreased. However, small population of the caudate neurons, which strongly increased their firing in sleep, was found in the second cat too. It is proposed that these neurons are inhibitory neurons, which arrange the block of propagation of the cortical signals to the caudate nucleus in sleep. (I.N. Pigarev, E.I. Rodionova).

In the morphological study it was shown that in the retina of the frog (Rana temporaria), ganglion cells projecting to the basal nucleus of the accessory optic system form large unistratified dendritic trees spreading in OFF sublayer of the inner plexiform layer, close to the amacrine cells. A small proportion of ganglion cells (about 5%) had displaced somata located at the inner margin of the inner nuclear layer, and their morphology and branching level were identical to orthotopic cells. The morphometric analysis have shown that the soma areas of ganglion cells located in midperipheral zone of the retina are at the range from 102 mkm^2 to 358 mkm^2 (mean sizes 198.7 +/- 54.5 mkm^2). The dendritic field areas varied in size from 0.04 to 0.16 mm^2 (mean area 0.08 +/- 0.3 mm^2). These data allow to classified ganglion cells projecting to the accessory optic system as large neurons of the retina. (T.A. Podugolnikova).

The measurement of frequency threshold curves using the electrical activity of auditory interneurons of prothoracic ganglion was performed in noctuid moths. We have found the evidence of active tuning of the auditory system to the stimulus carrier frequency. This effect also caused 6-8 times increase in the auditory sensitivity. Basing on several features of auditory responses recorded, particularly on the dynamics of neuronal firing in the near-threshold area, we conclude that in our experiments some high-quality mechanical resonance within the tympanic organ shifted downwards from above 100 kHz. This effect is not observed in narcotized or heavily injured insects. (D.N. Lapshin)

The laboratory hybrids between closely related grasshopper species *Chorthippus albomarginatus* and *Ch. oschei*, *Ch. oschei* and *Ch. karelini* were obtained in second generation. We studied a viability of the hybrids. The acoustic signals of the hybrid males were recorded and analyzed. In the behavioural experiments, the mating preferences of the hybrid females were studied. Embryonic and larval inviability was shown to be higher in F2 hybrids than in parental species and F1 hybrids. This evidences that some genetic isolating barriers between these species were established. The song analysis showed that the signals of F2 hybrid males were very similar to the signals in the F1 hybrids. The songs of the hybrids between *Ch. albomarginatus* and *Ch. oschei* were intermediate between parental species, however there was some shift to the song of the *Ch. albomarginatus*. The songs of the males obtained from the backcrosses with parental species were shifted to the parental songs. Song

analysis of the laboratory hybrids allows revising the natural hybrid populations studied in the contact zone of the two species *Ch. albomarginatus* and *Ch. oschei* (Vedenina, Helversen, 2003). In particular, the song analysis allows distinguishing the hybrid males from the backcrosses in the natural populations. Behavioural experiments with the hybrid females showed a very low selectivity in the mating preferences of these females: they did not distinguish between the hybrid males and the males of the parental species. Thus, in the mixed populations, the hybrid females could compete with the females of the pure species when attracting the males; mating success of the hybrid males could be lower depending on the population structure and the ratio of the females of different types (V.Yu. Vedenina, A.K. Panjutin).

The technical and clinical tests of the device "KChSM-D" are carried out and the tests of devices "Raduga-3 DL" and "Raduga-3 L" will be carried out. After certification a factory FTsDT NPO "Soyuz" begins serial manufacture of these devices. The decision on distribution of the patent on the invention " Way of diagnostics of defects of sight and device for its realization " (June 7, 2004) is received". (K.V. Golubtsov, O.Yu. Orlov).

GRANTS FROM:

- **Basic Research Program of Presidium Russian Academy of Sciences "Fundamental sciences for medicine":** Project "Computer system development for multi-focal KChSM-diagnostics (CHIASMA)". (K.V. Golubtsov)
- **Biological Department of Russian Academy of Sciences Basic Research Program "Integrative mechanisms function regulation in organism":** Project "Research of visual perception constancy and visual illusions mechanisms" (V.A. Bastakov)
- **Russian Foundation of Basic Research (№ 02-04-48256):** "Frequency tuning of the hearing system of noctuid moths (Lepidoptera, Noctuidae) (D. N. Lapshin).
- **Russian Foundation of Basic Research (№ 03-04-49372):** "Study of effectiveness of the cortical excitatory protections on caudate nucleus and putamen in sleep waking cycling and of the hypnogenic effect of electrical microstimulation of caudate nucleus". (E.I. Rodionova).
- **Russian Foundation of Basic Research (No. 04-04-49430):** Direction-selective visual responses in retinal projections to the fish tectum: classification, spatial and colour properties, neural mechanisms (V.V. Maximov).
- **Russian Foundation of Basic Research (No. 04-04-48359):** "Contribution of the visual areas V1 and frontal eye field neurons in the optic flow analysis in wakefulness, and their participation in the analysis of visceral information during sleep". (I.N. Pigarev).
- **Russian Foundation of Basic Research (No. 04-04-48894)** Comparative study of accommodation mechanisms in human eye and in vertebrates. (G.I. Rozhkova).
- **Russian Foundation of Basic Research (No. 04-04-48883):** Hybridization and barriers to gene exchange between closely related grasshopper species of the Chorthippus albomarginatus-group (Insecta: Orthoptera) (V.Yu. Vedenina)
- **Samsung Electronics Co., Ltd. R&D Center SAIT** Korea " Perceived contrast enhancement in displayed images under viewing illuminants with high intensity levels". (V.A. Bastakov).

WORK WITH YOUNG SCIENTISTS

- December, 23 2004 D. P. Nikolaev has defended his PhD thesis "Algorithms of colour segmentation applied in conditions of complex illumination of a scene" (scientific leading prof. A.I. Chulikov, scientific consultant prof. G.I. Rozhkova).
- December, 6 декабря 2004 S.V. Ogurtsov has defended his PhD thesis "Imprinting on native pond odour as one of mechanisms of chemo-orientation in Anura" (scientific leading prof. B.D. Vasiliev and Dr. V.A. Bastakov).
- At our laboratory two post-grads are studding now – V.A. Ognivov and A.A. Loshkarev.
- Head of Laboratory Dr. V.A. Bastakov does lecturing for 3d 5th year students Interpreting Department of Moscow State Linguistic University.
- Prof. G.I. Rozhkova is professor-consultant Faculty of Defectology of Moscow State Pedagogical University.
- Dr. E.M. Maximova does lecturing for 4th year students Faculty of Biology of Lomonosov Moscow State University.
- Prof. L.S. Lebedev, DrSci (Biol.) I.N. Pigarev, DrSci (Biol.) D.N. Lapshin and Dr. O.Yu. Orlov are giving practical classes, leading term-works and diploma research works for students of Faculty of Fundamental Medicine, Faculty of Physics and Faculty of Mechanics and Mathematics of Lomonosov Moscow State University and Moscow State Technical University "Stankin".

PUBLICATIONS IN 2004

Articles

1. Лапшин Д.Н., Воронцов Д.Д. Процессы захвата и сопровождения акустического сигнала слуховой системой совок (Noctuidae, Lepidoptera) // Сенсорные системы. 2004, Т. 18. № 3. С. 265-272.
2. Лемак М.С., Хахалин А.С., Максимов В.В., Максимов П.В., Воронин Л.Л. Новый вид обработки сигналов в синапсах головного мозга: Положительная эфаптическая внутрисинаптическая обратная связь // Нейрокомпьютеры: разработка, применение. 2004. № 2-3. С. 21-32.
3. Максимов В.В., Максимов П.В. Зрительная ассоциативная память и эффект ориентационно-обусловленного цветового последействия // Биофизика. 2004. Т. 49. № 5. С. 920-927.
4. Николаев Д.П. Алгоритмы цветовой сегментации, применимые в условиях сложного освещения сцены // Автореферат на соискание ученой степени кандидата физико-математических наук. Москва. Физический факультет МГУ им. М. В. Ломоносова. 2004.
5. Рожкова Г.И., Токарева В.С., Николаев Д.П., Огнивов В.В. Основные типы зависимости остроты зрения от расстояния у человека в разном возрасте по результатам дискриминантного анализа // Сенсорные системы. 2004. Т. 18. № 4. С. 330-338.
6. Nikolaev D.P., Nikolayev P.P. Linear color segmentation and its implementation // Computer Vision and Image Understanding. 2004. V. 94 (Special issue on colour for image indexing and retrieval). P. 115-139.
7. Rodionova E.I., Revischin A.V., Pigarev I.N. Distant cortical locations of the upper and lower quadrants represented by neurons with elongated and radially oriented receptive fields // Exp. Brain Res. 2004. Oct. V. 158. No 3. P. 373-377.

Institute for Information Transmission Problems

In print

1. Веденина В.Ю. Акустическая коммуникация и половой отбор у прямокрылых насекомых (Insecta: Orthoptera). Журнал общей биологии.
2. Лапшин Д.Н. Особенности восприятия совками (Noctuidae, Lepidoptera) непрерывной последовательности коротких акустических щелчков // Сенсорные системы.
3. Лапшин Д.Н., Воронцов Д.Д. Ретрансляция эхоподобных сигналов: метод и результаты исследований на ночных чешуекрых // Журнал общей биологии.
4. Максимова Е.М., Бастаков В.А. Физиология зрительного анализатора. – Руководство к практическим занятиям по курсу физиологии животных и человека. М.: Изд-во МГУ.
5. Подугольникова Т.А., Кондрашев С.Л., Пущин И.И. Морфология ганглиозных клеток сетчатки лягушки *Rana dybowskii*, образующих проекцию в зрительный тектум // Сенсорные системы.
6. Рожкова Г.И., Токарева В.С., Огнивов В.В., Бастаков В.А. Геометрические зрительные иллюзии и механизмы константности восприятия размера у детей // Сенсорные системы.
7. Maximov V.V., Maximova E.M. and Maximov P.V. Directional selectivity in the goldfish tectum revisited // Annals of the New York Academy of Sciences. Rozhkova G.I., Podugolnikova T.A., Vasiljeva N.N. Visual acuity in 5-7 year old children: individual variability and dependence on observation distance // Ophtalmic and Physiological Optics.

Conference reports

1. Афонин Д.Г., Николаев Д.П., Карпенко С.М. Экономная схема вычисления преобразования Хафа для сжатия видеопотоков. // Материалы 14-ой международной крымской конференции "СВЧ-техника и телекоммуникационные технологии" (КрыМиКо'2004). Севастополь: Изд-во СевНТУ. 2004. С. 204-205.
2. Божкова В.П., Суровичева Н.С., Николаев Д.П., Лебедев Д.Г. О структуре распределения показателей плавного прослеживания движущихся стимулов у студентов // Искусственные интеллектуальные системы и Интеллектуальные САПР. Труды международной конференции IEEE AIS'04 и CAD-2004. М.: Физматлит. 2004. Т. 2. С. 266-272.
3. Веденина В.Ю. Культивирование саранчовых рода *Chorthippus* (Insecta: Orthoptera) // Тезисы конференции «Зоокультура и биологические ресурсы». МСХА и ИПЭЭ РАН, Москва. 2004.
4. Веденина В.Ю. Исследование изолирующих механизмов у близкородственных видов саранчовых путем гибридизации в условиях лабораторной культуры. Тезисы конференции «Беспозвоночные в коллекциях зоопарков». Московский Зоопарк. Москва. 2004.
5. Голубцов К.В., Трунов В.Г., Айду Э.А.-И., Зигангиров Д.К., Баринова Н.Е. Компьютерная система для исследования КЧСМ // Тезисы докладов Конференции "Фундаментальные науки – медицине" (г. Москва, 02-03 декабря 2004 г., РАН). С. 117.
6. Горбунов В.В., Максимова Е.М., Максимов В.В. Зависимость ответов детекторов направления движения сетчатки рыб от скорости стимулов // Рос. физиол. журн. им. И.М. Сеченова. 2004. Т. 90. № 8 (часть 1) С. 303.
7. Карпенко С.М., Николаев Д.П., Николаев П.П., Постников В.В. Быстрое преобразование Хафа с управляемой робастностью // Искусственные интел-

лектуальные системы и Интеллектуальные САПР. Труды международной конференции IEEE AIS'04 и CAD-2004. М.: Физматлит, 2004. Т. 2. С. 303-309.

8. Максимова Е.М., Левичкина Е.В., Денисенко А.В. Морфология дирекционально-избирательных ганглиозных клеток (ДИ ГК) сетчатки карася, трассированных DiI // Рос. физиол. журн. им. И.М. Сеченова. 2004. Т. 90. № 8 (часть 1). С. 323-324.

9. Максимов В.В., Максимова Е.М., Максимов П.В. Шесть типов дирекционально-избирательных зрительных ответов в ретинальных проекциях в тектуме рыб // Рос. физиол. журн. им. И.М. Сеченова. 2004. Т. 90. № 8 (часть 1). С. 324.

10. Николаев Д.П., Карпенко С.М., Постников В.В. Преобразование цветного изображение в монохромное с сохранением градиентной структуры // Искусственные интеллектуальные системы и Интеллектуальные САПР. Труды международной конференции IEEE AIS'04 и CAD-2004. М.: Физматлит. 2004. Т. 2. С. 320-323.

11. Николаев П.П., Николаев Д.П. Сравнительный анализ гауссовской и линейных спектральных моделей в задаче оценки окраски // Искусственные интеллектуальные системы и Интеллектуальные САПР. Труды международной конференции IEEE AIS'04 и CAD-2004. М.: Физматлит. 2004. Т. 2. С. 323-328.

12. Огнивов В.В., Рожкова Г.И., Токарева В.С., Бастаков В.А. Системный подход к оценки развития зрительных функций // Материалы международной научной конференции "Физиология развития человека", посвященной 60-летию Института возрастной физиологии. Альманах "Новые исследования" 2004. М.: Вердена. № 1-2. С 285-286.

13. Рожкова Г.И., Токарева В.С., Огнивов В.В., Бастаков В.А. Геометрические иллюзии и точность глазомера у детей и взрослых // Рос. физиол. журн. им. И.М. Сеченова. 2004. Т. 90. № 8 (часть 1).

14. Akimov N.P., Maximova E.M. and Maximov V.V. Receptive-field sizes of the direction-selective units in the goldfish tectum // The 7th Congress of the International Society for Neuroethology, Abstracts. 2004. Nyborg. P. 189.

15. Bastakov V.A. Visual illusions associated with distance estimation mechanisms in frog and toads. // The 7th Congress of the International Society for Neuroethology, Abstracts. 2004. Nyborg. P. 191.

16. Chervova L.S., Lapshin D.N. Pain sensitivity of fishes and analgesia induced by opioid and nonopioid agents // Proceedings of 4th Int. Iran and Russia Conf. Agriculture and natural resources. ShahreKord, Iran.: Published by Shahre Kord Univ., 2004, Eds.: S.J. Sadatinejad et al., P. 1420-1425.

17. Damjanovich I., Byzov A.L., Bowmaker J.K., Gachich Z., Utina I.A., Maximova E.M., Michkovich B., Andjus R.K. Photopic vision in eels - evidences of color discrimination // The 22nd International Symposium on Biophysics – Book of Abstracts. 2004. Sv. Stefan & Belgrade, W2:P1.

18. Golovkin M., Gorbunov V., Maximova E. and Maximov V. Receptive-field structure of direction-selective ganglion cells projecting to the goldfish tectum // The 22nd International Symposium on Biophysics - Book of Abstracts. 2004. Sv. Stefan & Belgrade. S1:P12.

19. Maximov P.V., Maximov V.V. Visual associative memory with omitted inhibitory synaptic connections: Is it still able to improve the quality of distorted images? // III International Optical Congress 'Optics – XXI Century' Topical Meeting on Optoinformatics – Book of Abstracts. 2004. Saint-Petersburg. P. 32-33.

20. Maximov V.V., Maximova E.M., Maximov P.V. Types of direction-selective inputs to the goldfish tectum // The 7th Congress of the International Society for Neuroethology, Abstracts. 2004. Nyborg. P. 190.
21. Maximova E.M., Govardovskii V.I., Maximov P.V., Orlov O.Yu., Maximov V.V. Colour-blindness of the direction-selective ganglion cells in the fish retina // The 7th Congress of the International Society for Neuroethology, Abstracts. 2004. Nyborg. P. 188.
22. Maximov V. Direction-selective inputs to the goldfish tectum opticum // The 22nd International Symposium on Biophysics – Book of Abstracts. 2004. Sv. Stefan & Belgrade. S1:P4.
23. Maximova E., Govardovskii V., Maximov P., Maximov V. Spectral sensitivity of direction-selective ganglion cells in the fish retina // The 22nd International Symposium on Biophysics – Book of Abstracts. 2004. Sv. Stefan & Belgrade, S1:P11.
24. Vedenina V.Yu. The inheritance of courtship songs and female preference in two sibling grasshopper species (Orthoptera: Gomphocerinae: *Chorthippus*) // Proceedings of Heuschrecken Arbeitsgruppentreffens in Mitwitz, Germany. March. 2004.