R&D Spirits

Search for Ideal Image Presentation Technology for Human Visual System

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What is the ideal image for human viewing? Senior Research Scientist Shin'ya Nishida of the Sensory and Motor Research Group of the NTT Communication Science Laboratories aims to provide the answer to this question through his research into the mechanism via which the brain "sees" things. The editors spoke with Dr. Nishida about his theory on the asynchronous perception of color and motion, a theory that may lead to the development of new technology and the changing of paradigms in brain studies.

Psychophysics approach to the human "viewing" mechanism

Editor: What is the main theme of your research group?

Nishida: Our group is conducting basic research into the relationship between the human senses and communication. My personal field of research deals with human vision. It has been proven recently in brain studies that when we see an apple falling from a tree, for example, our brain first processes separately the data relating to color, shape, and motion, and afterward integrates those elements to recognize the falling apple. But that leaves us with the new question of how the brain integrates the data it processes. In search for an answer to that question, I am researching the brain's functions by examining the human perception of various visual illusions. The field I work in is called psychophysics. Although some people may think it unusual for NTT to be conducting psychophysical research, visual presentation play a very important role in communication today. In a sense, our group's research is to provide basis of human communications technology.

E: Could you outline your group's current research for our readers?

N: One of our research themes relates to the human perception of the pattern of surface light reflectance. In a visual illusion created by Professor Adelson of MIT, with whom our group is conducting joint research, the human eye perceives two images of the same gray color to be completely different colors because of the context they are embedded in. This is because what the human visual system sees is the pattern of light reflection of the surface, rather than the absolute magnitude of reflected light. By taking into account changes in illumination, one sees surface color the same no matter what the circumstances. At the same time, we also know that our ability of perceiving constant surface reflectance is not perfect due to limitations of the brain processing. We would like to know what actually happens in our brain, and to use the outcome of the research for developing an easy way to synthesize an image that looks similar to the original real image without matching image details.

Another theme is visual presentation through slits. If a moving pattern is viewed through a stationary slit the eyes store the visual information that passes before it and the brain then pulls the separate pieces of information together into one complete image (see Selected Papers in this publication, "Human Visual

Mechanism," p. 13). Although this presentation technique was developed as early as 30 years ago, I acquired a renewed interest in it after I saw an animated advertising display that applied the old technique. The effect of the display cannot be sufficiently explained by currently prevailing notion that the brain processes shape and movement separately. The spatial resolution of the display was extremely low, and when the character patterns in the display were not moving they were almost unreadable. When moving, however, the characters were completely readable. In short, information regarding movement was used to increase the amount of information regarding shape. It seemed to me that by studying this phenomenon further our group might be able to understand how the brain integrates the shape and movement of images.

Unique "Time Marker" theory derived by studying contradictions in accepted theories

E: What is the main point in your research?

N: The main point in our research is the unique theory we have proposed concerning the visual system in the brain. As mentioned, it has been long believed that the brain processes separately the various types of visual information it receives. As suggested in the slit discussion above, however, I do not believe that the brain completely separates the visual information it receives. One result of our research is seen in Fig. 1, which shows the interaction between movement and shape. While looking at the center of the figure, rotate the windmill on both sides for a while. After you stop rotating the images, you will see them appear to rotate in the reversed directions; at the same time, the orientations appear to be tilted although the windmills are physically oriented vertically. In this experiment, the sense of shape has been warped by movement information produced by a visual illusion. If the brain were processing shape and movement information separately, such an interaction would not occur. The fact that the interaction does occur suggests that in order to smoothly process the changes in shape, the brain used movement information to predict the succeeding sequence of events.

Another example that argues against the notion of separate processing is the visual illusion called "perceptual asynchrony of color and motion." This visual illusion shows that color and motion can actually be synchronous while they do not appear to be so, and when they actually are not synchronous they can appear to be so (see Selected Papers in this magazine,

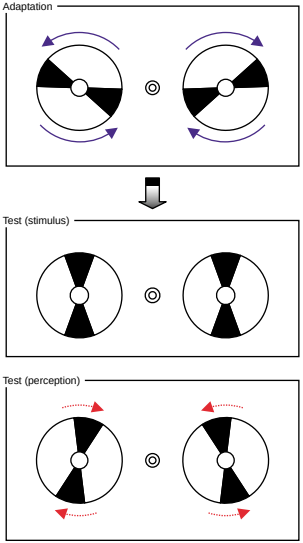


Fig. 1. Interaction between movement and shape.

"Human Visual Mechanism," p. 15). This time lag has been explained by saying that the brain processes color faster than it processes motion. In the asynchrony of color and motion, however, as the exchange cycle becomes longer the asynchrony dissipates. Also, in experiments where we measured the length of time it took to respond separately to changes in color and motion, absolutely no time disparity was observed between the two. The hypothesis that the brain processes color faster than it processes motion thus cannot completely explain the asynchrony of color and motion. To replace that time processing hypothesis, we developed a "time marker" hypothesis in which we based time-related judgments on a comparison of salient features in the stimulus sequence (time markers). Because it is difficult for humans to discern the instant that motion changes direction—at

high speeds it is next to impossible—we surmise that asynchrony arises. The time marker hypothesis is a fresh approach in that it says the brain processes separately both the contents of an events and the time the events occurs. Clear evidence that our hypothesis is correct would lead to the changing of paradigms in brain studies.

E: What is the significance to society-at-large of research that clarifies the brain's visual processing mechanisms?

N: Because next-generation communications technology will rely heavily on animation, we believe that knowledge about the brain's visual processing mechanisms will play a major role in developing that technology. An example is an unexpected noise problem for DLP (digital light processing) projectors and plasma displays. These problems probably emerged because the products were developed without a complete appreciation of human sensory characteristics. In other words, the products were developed based on the belief that human visual system cannot detect rapid stimulus changes regardless of the pattern of eye movements. In contrast, although the NTSC (National Television Systems Committee) color television format projects a low-resolution image on television screens, the resultant image is of acceptable quality when viewed by the human eye. This result is probably due to unintentional tuning by the product development team. It can also be said that the thinking mentioned earlier—in talking about research related to motion and shape, where information about motion is used for predicting the succeeding sequence of shape events—closely resembles moving picture compression technology, such as that used in the MPEG (Moving Picture Experts Group) format. In these ways, the mechanism via which humans see things is at the root of all motion picture technology.

E: How might the results of your research be utilized?

N: The results of our research will directly affect the development of products such as those just mentioned, including new displays. In addition, features like those expressed in words like "easy to see" and "flickering feeling" will eventually be quantified. By proposing a scientific basis for them our group will be able to provide guidelines about moving images to a wide audience. From that viewpoint, the senior research professor in our group is studying the effects that moving images exert on the health and safety on human beings. At any rate, this is research conducted by NTT and the results are certain to be put to good use in developing communications technology that utilizes multi-modal information, including information from the auditory sense, as well as time-space information.

Research into visual system allows self to be research subject

E: What was your principal motivation for entering the field of research into the visual system?

N: The original motivation for me to begin the research I am doing today was that I wanted to know more about the functions of my own brain. When I was young I was a bit philosophical and I remember wondering what it actually meant when a person said "there's something over there." But rather than taking a humanities approach to answering that question, I searched for a scientific answer. Although I originally also had an interest in human cognition as well as language, I gradually zoned in naturally toward human vision, a field I could approach scientifically through experimentation.

E: What were the reasons for choosing NTT as the venue for your research?

N: Research into the visual system and visual information is a relatively new field for NTT. In fact, many members of my research group were hired midway through their professional careers. I came to NTT, for example, from the ATR Auditory and Visual Perception Laboratories. Dr. Takao Sato, currently a professor at the University of Tokyo, was seconded from NTT to ATR at the time. Several months after he returned to NTT, I moved here to work with him. I think the basic choice for researchers is either to conduct a scientific research in university together with graduate students or to plug away in a research institute. Different people think differently about which is best, of course, but conducting research in a research institute in the private sector is much more attractive to me. There is also more freedom for individual initiative in a research institute. Based on that thinking, and because I would be able to work with other researchers in fields close to my own, I chose to join NTT.

E: What do you consider most interesting about your research?

N: My research theme is very close to my own life. Anyone with normal senses can easily experience visual illusions, and can enjoy them the instant they see them. Although we use volunteers in our laboratory experiments, we often also take measurements using ourselves as subjects. At such times we are investigating how we ourselves see things, and we gradually come to understand our own visual capabilities. As well, human vision is a research field that is widely open. It is as if nothing is understood for certain yet. In fact, in terms of understanding the human vision, our visual neuroscientists are probably no more than half a step ahead of those reading this article. It can be said that our research is in an area where one wonders if it is truly possible to find answers. So while our area of research is very friendly and familiar, since it deals with the human sense of sight, there is no end to the work that must be done. Those are some of the reasons why our research is so interesting.

NTT engages in wide-ranging joint international research

E: What is your group currently doing in the area of international activities?

N: Because my papers are only published overseas, perhaps all my research activities can be called international. Other than my personal research I am also involved a bit with the work of the Asian Association for Vision Research. But I have not yet become a member of any committee, nor have I served as an editor of the international scientific journal. Perhaps I have not reached that age yet. (laughter) I do receive many papers for review, however; in 2002, for example, I reviewed about ten papers. This is not many, since researchers in other countries say they review many more than that. For a Japanese, however, writing referee's reports in addition to journal papers in English requires quite an effort compared to researchers native to English. I view that effort, however, as a part of my research.

E: Does your group participate in joint research with overseas researchers?

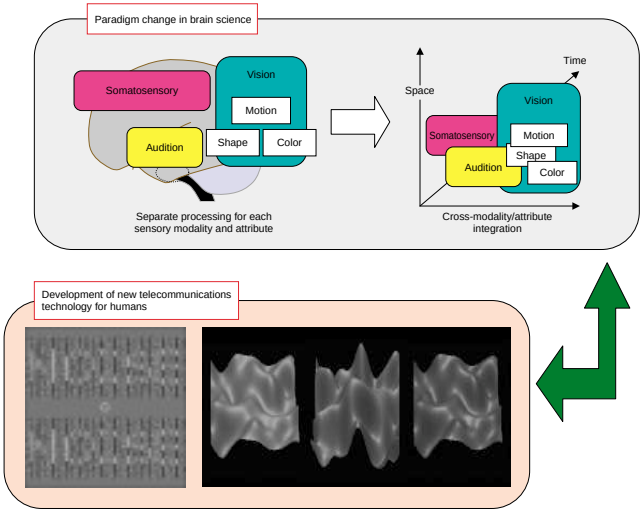
N: Even in the context of the overall NTT organization, our group is quite busy with joint overseas research. One area of such research is the revolving windmill visual illusion introduced earlier, as well as studies related to the asynchrony of color and motion. While I was a visiting researcher in England at University College London for a year from 1998, I studied with researchers there and was able to propose several new ideas. There is also an ongoing joint research project between NTT and MIT. In that project, Professor Adelson of MIT, who developed the gray visual illusion I mentioned earlier, is my research partner. Other joint research in our group is being conducted with the Psychophysics Lab of Dr. Shinsuke Shimojo, one of our research professors, at California Institute of Technology. Our group is also working jointly with researchers in Australia. With Massachusetts General Hospital, meanwhile, we are cooperating in functional brain imaging. Being able to work with well-known professors in various fields is a valuable experience for everyone in our group and we learn much in the process.

E: How is NTT's work in the field of visual science evaluated overseas?

N: NTT's research in the field of visual science is still fairly new, and we have not yet developed to the level of institutions such as MIT. We are proud to say, however, that in Japan we rank among the most active research groups in the field. Actually, we sometimes hear comments from overseas about the work our group is doing. Some people are concerned that as a private-sector research institute we might follow the same path that Bell Labs took. Very definitely, the situation in Japan differs from that in the U.S., where industry and academia are linked closely together. If an organization like NTT does not conduct basic research in various areas the country itself will suffer severe losses. Our group manager, however, says clearly, "NTT should not make the same mistakes AT&T made." The members of our group have taken those words to heart by relating that message to the outside at every opportunity and by continuing to make efforts to realize good results from our research.

E: Please share with us your thoughts about the future.

N: When I was a bit younger, I did not have a clear view on how to relate my basic scientific studies with development of telecommunications technology. In recent years, however, perhaps because I gained



General scope of the study. Our brain may process different sensory modalities and attributes in an integrative fashion on the unified spatiotemporal coordinates, rather than analysing them separately in distinct modules, as has been widely believed. Proving this idea will lead to a paradigm change in brain science, which in turn will provide basis for the development of novel telecommunications technologies for human.

greater leeway, I continue my studies not only because I enjoy the work but also because I hope it will serve some higher purpose in society. In other words, my research has significance not only in science but also for how it might influence future technological developments. That, of course, is not an easy thing to do, but it is the stance I want to take in my future studies.

E: How do you personally view the role of NTT Communication Science Laboratories?

N: Although the NTT Communication Science Laboratories are part of a private enterprise, the members of our group are not forced to conduct application studies. We are pretty much afforded the freedom to conduct the research we want to, and I am quite happy to be associated with the labs. Being given much freedom, however, does not mean we can study anything we like. It merely means we can conduct our research at the pace we determine to be optimal. And we are rewarded for our successes. In order to support that status we are required to be fully responsible for, and sufficiently capable of, completing our research. Although I am sometimes not 100 percent certain that I have such capabilities, I always conduct my research while being fully aware of its social and scientific significance, and I hope I can continue providing acceptable research results.

Interviewee Profile

1985 – Graduated from Kyoto University, Faculty of Philosophy, with B.A. in Psychology
1990 – Finished the Ph. D. course in psychology from Kyoto University, Faculty of Literature
1990 – Joined ATR Auditory and Visual Perception Laboratories as researcher
1992 – Joined NTT
1996 – Earned Ph. D. in literature from Kyoto University
1997 – Invited to University College London as researcher
1999 – Current position

Selected Publications

S. Nishida and T. Sato, "Motion aftereffect with flickering test patterns reveals higher stages of motion processing," Vision Research, Vol. 35, pp. 477-490, 1995.
S. Nishida, T. Ledgeway, and M. Edwards, "Dual multiple-scale processing for motion in the human visual system," Vision Research, Vol. 37, pp. 2685-2698, 1997.
S. Nishida and M. Shinya, "Use of image-based information in judgments of surface reflectance properties," Journal of the Optical Society of America, Am, Vol. 15, pp. 2951-2965, 1998.
S. Nishida and A. Johnston, "Influence of motion signals on the perceived position of spatial pattern," Nature, 397, pp. 610-612, 1999.
S. Nishida and H. Ashida, "A hierarchical structure of motion system revealed by interocular transfer of flicker motion aftereffects," Vision Research, Vol. 40, pp. 265-278, 2000.
S. Shimojo, Y. Kamitani, and S. Nishida, "Afterimage of perceptually filled-in surface," Science, 293, pp. 1677-1680, 2001.
S. Nishida, I. Motoyoshi, R. A. Andersen, and S. Shimojo, "Gaze modulation of visual aftereffects," Vision Research, Vol. 43, pp. 639-649, 2003.

Membership in Professional Organizations

Association for Research in Vision and Ophthalmology and the Optical Society of America