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COMPARATIVE STUDY OF VISUAL PERCEPTION USING JOHANSSON'S STIMULI

*Emi Omori**

Since Johansson's (1973) pioneering work, biological information from the motion of points of light has been studied extensively. Perceptions induced by observation of moving points of light in non-humans, as well as human subjects, may aid in our understanding of how organisms extract and analyze information in their visual world. The present paper summarizes the results of an experiment in which pigeons and human subjects discriminated between moving points of light produced by a live pigeon and moving points of light produced by a mechanical toy. The data suggest that non-human animals, as well as humans, correctly infer differences in the generation of the two sources of observed motion.

Components of Visual Perception

Perception does not create a precise copy of the real world in the mind of those who observe it. Rather, it is a process which involves the ability to reconstruct the external world from the limited stimulus information acquired through the senses. In fact, in many cases, only limited features of the stimulus are sufficient to evoke the perception. In this sense, the observer can be "tricked" into seeing "reality" by illusion. Optical illusion provides an example of this. As Wertheimer (1912) pointed out, successively presenting still images to an observer will produce the perception of motion. Illusions of size occur when looking into the Ames room (Ittleson, 1952) because the distances of furnishings expected there are different from the actual ones. These phenomena demonstrate that the observer does not use every piece of information that the environment presents when interpreting events in the external world.

Johansson's Biological Motion

The perception of motion is another case in which the observer can be tricked into experiencing reality through illusion. The Swedish psychologist, Gunner Johansson (1973), studied the relation between motion and perception using dots of light moving on a dark background. He placed the light sources on four corners of a rectangle and moved them along diagonal lines, either toward the center or away from the center. The former situation evoked the perception of a rectangle moving away from the observer, while the latter situation evoked the perception of a rectangle approaching the observer. He assumed that what the observer does in seeing motion is to analyze and divide the stimulus into a common vector elements (vector toward/away the center) and the invariant structure (the rectangle).

Next he placed a point light source on the major joints of a human body and presented the image of the body with the illuminated points at the joints on a screen with a dark background. When the image is still, an observer sees randomly distributed dots of light. Once the human body on the screen starts to walk, the observer "sees" a walking human figure. The observer can identify the gender and age of the walking figure. He can also identify the person who is walking if he knows the person. Because such stimuli carry information of biological importance, Johansson named the stimuli "Biological Motion".

Cutting (1978) tried to determine the key factor underlying sex discrimination. Analyzing light point motion of walking humans of both sexes, Cutting proposed the "Center of Moment (Cm)" hypothesis. Cm is a point in a body deduced from the positions of shoulders and hipbone and the relative position of that point within a length of torso. By varying the value of the Cm, Cutting artificially created light

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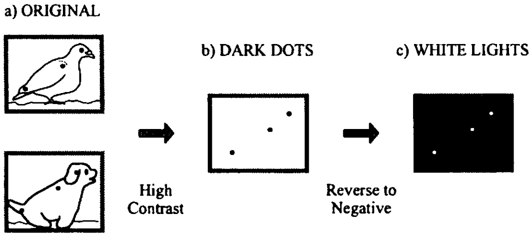

Fig. 1. Process of making point light motion from the video of original subjects. The white pigeon and the toy dog were used as subjects (a). The video was processed into sharper contrast (b) and then reversed to negative (c).

point motions of walking humans and let observers estimate how masculine or feminine each stimulus appeared to be. Although the artificial stimuli used were less natural those obtained from the actual motion of walking humans, it turned out that there exists a few hypernomal stimuli within these artificial stimuli. The term hypernormal is used here because these few stimuli were considered more feminine or more masculine than the Cms produced by the movements of real women and men. This experiment demonstrates that motion is an important element in visual perception and that it may provide biologically meaningful information.

Comparative Studies of Light Point Motion

The potential biological importance of information about light point motion has motivated several researchers to undertake comparative studies. Either in developmental or in between species. the first problem is to see what sort of capabilities make it possible for human observers to obtain biologically important information from moving dots of light.

For human observers a major characteristics of light point motion perception is the vivid and obvious impression of a moving human body. This occurs within 1 second, and occurs almost without exception (Johansson, 1973). This suggests that such perceptions are of more basic rather than higher process and therefore are likely to be found not only in humans. However, human perception is not necessarily the same as the perception of other animals. Moreover, the humans' ability to manipulate and to interpret sensory information and signals casts doubt on the generality of the characteristic of human perception. Interpreting dots on the surface of TV monitor as a configuration that represents a conspecific individual may be an activity similar to that involved in understanding line drawings or reading letters or words, activities presumably not found in non-human animals.

Several comparative studies, however, suggest that the ability to interpret moving dots arising from the movement of an individual does not belong exclusively to human adults. For example, Fox and McDaniel (1982) found that four to six month old human infants prefer normal light point motion produced by a walking human to distorted or upside-down motion. They concluded that the mechanisms underlying this sensitivity toward naturalness must be intrinsic rather than acquired later in life.

There are three studies of light point motion using non-human subjects, namely, bottlenose dolphins, cats and pigeons. Herman *et al.* (1990) conducted an experiment with two bottlenose dolphins who were proficient in interpreting gesture language signs and who obeyed these signs when they were shown. In the study, they made it clear that the dolphins could follow the signs presented on a TV monitor. Then the body of the signer was gradually occluded to a point in which the dolphins could see only the signer's palms and finally only two dots of light produced by the movement of the palms. The dolphins correctly responded to the signs at above chance level throughout the experiment, although there was a major decrement in performance when the only information was the movement available in the light point display.

Blake (1993) trained cats with two types of light points representing motions of a walking cat. One was normal movement and the other was either foiled or scrambled in various degrees. The cats were to choose one of two screens and the choice was considered correct if they chose the screen showing the normal motion. The cats learned to discriminate between those two types of displays. The discrimination generalized to novel normal light point motions arising from actions and directions of move-

Table 1. Number of key peck to each stimuli in test session and S+ratio

	training			novel			color		
	pigeon	toy	S+ratio	pigeon	toy	S+ratio	pigeon	toy	S+ratio
S1	12	7	0.63	7	0	1.00**	16	28	0.36
S2	92	13	0.88**	20	20	0.50	35	28	0.56
S3	23	1	0.96**	62	9	0.87**	0	0	0
S4	36	88	0.71**	23	24	0.51	76	130	0.63**
S5	20	52	0.72**	3	7	0.70	17	15	0.47
S6	11	46	0.81**	10	29	0.74**	0	2	1.00
S7	9	114	0.93**	40	77	0.66**	3	61	0.95**
mean			0.80			0.71			0.57

**<0.01

ment different from those used in training. Responses in the presence of unnatural light point motion, those that were upside-down or speeded fast-forward, stayed low. Blake concluded from these results that cats are able to distinguish biological motion from foiled light point motion. He suggested that they might have used the connection of joints in a hierarchy involving nested movement of body parts to accomplish this discrimination.

Omori and Watanabe (1996) trained seven pigeons to discriminate between the light point motion produced by a pigeon and that of a toy dog whose motion was produced by batteries (see Fig. 1a). Under a go/no-go procedure all pigeons learned to discriminate between these two types of light point motion. The pigeons were then tested using novel light point motions of the same two types in order to check whether they were responding correctly as a result of their memorizing the stimuli used in training. Four of the seven pigeons generalized to the novel stimuli (see Table 1 and Fig. 2). Next, the pigeons were tested using the color films of the pigeon and the toy dog from which the moving dot stimuli were made (Fig. 1a). This was done in order to determine whether the pigeons experienced the light point motion during the experiment as representing the movement of the pigeon and the toy in a way similar to the experience of human subjects who perceive the moving dots as movement of a human body in the experiment of Johansson (1979).

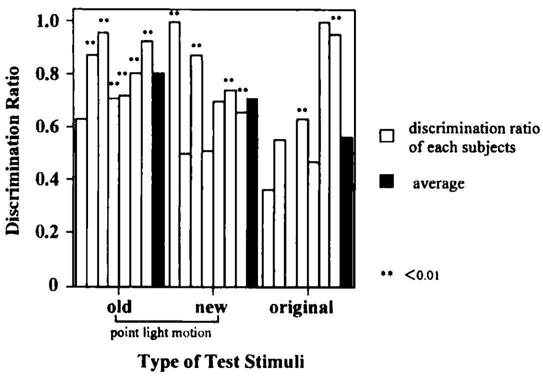

Fig. 2. In piont light motion test, the video used in the training phase and novel point light motion were used as stimuli. In original subject test, corresponding unprocessed color video of original subject was used as stimuli. 7 bars show each subjects' discrimination ratio in the test. Dark bars show the average discrimination of each type of test stimuli. Asteriscs (**) indicate p<0.01 by binominal test.

Two of the seven pigeons showed immediate transfer (Table 1 and Fig. 2). However, since the color films contained dots on the surface of the subject's body, there is still a need for another test using color films with no dots on the body surface of the subjects. In addition, because the test results differed greatly among subjects, additional subjects are needed in order to understand how and to what degree pigeons attribute light point motion to the movement of organisms.

Another finding of Omori and Watanabe (1996) was from an experiment with human subjects, using the same stimuli as those used in the above experiment. All twelve subjects acquired the discrimination between the two types of light point motion and showed close to perfect generalization to novel stimuli. However, only four subjects were able to describe what they saw, that is, only four subjects noticed that the light point motion they observed was produced by a walking bird. The stimuli used in this experiment contained only three dots of light. Johansson's (1973) study demonstrated that for human subjects five points of light are sufficient for people to attribute the motion to the movement of the human body. The difference between these two outcomes might be due to the number of dots or there might be conspecific priority or an effect of familiarity in understanding light point motion.

Conclusions

The two theories of motion perception described here, Johansson's visual vector analysis and Cutting's Cm analysis, represent efforts to create parsimonious explanations of perception of a moving individual from the motion of points of light. However, these theories do not deal with the origin of this perception. Is it innate or learned? Is the perception restricted to human observers? It is hard to define the border between those characteristics of object recognition and representation that are common to humans and non-human animals and those that are restricted to humans. Comparative studies attempt to answer this question. Although there is no way to prove that the animals in the experiments I cited perceived the moving dot patterns in the same way as the human subjects, they did accomplish the tasks the experimenters set up. It is, therefore, likely that animals share, to some degree, the organized way humans recognize moving points in motion.

Comparative studies using light point motion as stimuli may also be of value in understanding how different animal species extract information from their visual world. In an ethological sense, every animal species has developed, not only their peculiar color and form, but also behavior that distinguishes the species. In social animals, behavior is a major means of communication. Study of species recognition from light point motion is yet to begin. Development of techniques for the study of perception of animals using light point motion, would be useful in understanding interspecies identification and may help us to understand how animals recognize members of their own or other species. Such studies would enhance our understanding of animal recognition by supplying a means of extracting and analyzing the elements within the visual world that are an effective source of information to animals.

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