STUDY ON MOTION PERCEPTION IN SPORT SCENES USING BIOLOGICAL MOTION

Fumiaki Yoshitomi and Shuji Mori
Faculty of Information Science and Electrical Engineering, Kyushu University
yoshitof@brain.is.kyushu-u.ac.jp, mori@brain.is.kyushu-u.ac.jp

Abstract

Two experiments were conducted to investigate spatio-temporal characteristic of perception of karate offensive action using biological motion. In Experiment 1, the proportion of correct identification for karate attacks (high/middle, left/right, kick/punch) was measured by manipulating the number of point lights constituting biological motion stimuli. In Experiment 2, stimulus presentations were cut off at various timings. The results of those two experiments indicated that recognition of attack motion from point-light stimuli reflected spatio-temporal information in the stimuli, with little influence of anticipation from earlier motion.

Human perceptual system is flexible, adapting its processing mode to the environment. For example, expert athletes seem to develop efficient information processing for tasks and stimuli specific to their sports, by extensive training. Such perceptual processing possessed by experts is called expertise perception.

In sport science, two types of perceptual abilities have been investigated in possible relevance to top-athletes' successful performance (Mori, Ohtani, & Imanaka, 2002; Seya & Mori, 2007). One type includes visual functions such as static and dynamic visual acuity, area of view, eye movement, and simple reaction times. Some studies show superiority of athletes over non-athletes in those functions, while the others show no difference. Such inconsistencies seem to be due to inadequate methodologies and data analysis, and to the use of tasks and stimuli irrelevant to the sports. The other type of perceptual abilities investigated in sport science is cognitive skills, such as attention, anticipation, memory, and response mode. Research has shown that superiority of athletes over novices in those skills is most evident under situations which simulate real sport scenes (for a review, see William, Davids, & Williams, 1999).

In this study, we conducted psychophysical experiments using biological motion of sport action as stimuli. Biological motion shows human gait using a sparse display involving the motion of only a few key parts of the body (head, hand, knee etc.). These parts are identified using points of light which undergo motion. Compared with a complete display of human body (i.e. movie taken by a video camera), biological motion is better suited to study of spatial characteristics of perception of sport action. In a spatial occlusion task (Abernethy, 1990; Abernethy & Russell, 1987), where a particular part of the body is deleted from the stimulus presented to the observer, video pictures are insufficient as it is often difficult to identify boundaries between deleted parts and the remaining body, and it requires sophisticated image processing techniques. On the other hand, in the biological motion image, a single point-light correspond to a main part of the body, so that it is easy to delete that part while maintaining the naturalness of the image. However, biological motion images often fail to allow the accurate recognition of human kinematic motion when the number of point-lights in the images is small. This study examined whether and how human observers would

recognize and anticipate human information from limited information.

The biological motion of this study represented karate offensive actions. Karate is a good example of a competitive sport with high level of temporal and spatial constraints which require fast reactions (Mori et al., 2002; Seya & Mori, 2007). In sparring ("kumite"), two athletes face each other within a 2-m distance, making offensive attacks against each other. Karate athletes are required to detect opponent's action and respond to them in very little time. Thus the main purpose of this study is to examine how human observers recognize and anticipate kinematic motion from limited information. In addition, it is relatively easy to simulate the karate athlete's view of the play scene because the athlete faces only a single opponent, as compared to team sports like soccer and rugby.

Two experiments of this study investigated the minimum number of point-lights that led to accurate recognition of offensive action (Experiment 1), and temporal characteristics of that recognition using a temporal occlusion method (Experiment 2).

Experiment 1

Method

Participants. Participants were 15 males and 5 females with a mean age of 22.2 years in the range of 21-26. They had no experience or regular karate training. All participants had normal or corrected-to-normal vision and reported no known disorder in their visual function.

Apparatus and stimuli. A personal computer (DELL INSPIRON 8200) were used to control the experiment and generate stimuli that were front-projected onto a screen ($150 \times 110 cm$) using a projector (SONY YPD-MX10).

To create the biological motion stimuli, offensive actions of three blackbelt karate athletes were recorded using digital video cameras. Facing the camera, the athletes first took a ready stance, then executed the offensive action against a virtual opponent standing at the camera position. They demonstrated thrusting punches and kicks several times, from both left and right side, each action being aimed either at the upper or the middle level. A total of 100 actions were recorded and converted into point-light movies, or biological motion stimuli, by 2-D video motion analyzer (DKH Frame-DiasII). For each stimulus, 19 points were digitized on the body (head, superior margin of the sternum, navel, shoulders, cubiti, hands, hips, trochanter majors, knees, heels, toes). The points were white circles ($9.95 cd/cm^2$ in luminance) subtending visual angle of 0.54 deg in diameter and presented against a black background ($0.20 cd/cm^2$). Projected on the screen, the body represented by those circles subtended approximately $49.9° \times 63.0°$ in height and width that matched the real perspective of an athlete standing 2 m away. The mean duration of stimulus presentation, from the ready stance to the end of offensive action, was 5sec in the range of 2-8sec.

In Experiment 1, the number of presented points of the biological motion stimuli were manipulated to be 4, 6, 8, 10, 12, 14, 16, 19. For each number, the presentation points were distributed evenly in 5 body areas (central torso plus head, upper-left from the shoulder, upper-right from the shoulder, lower-left, lower-right), to represent the full body even when the number was small. The points presented were selected randomly on each trial.

Procedure. The experiment was conducted in a dark room. Participants were dark-adapted for 15 minutes prior to the experiment. During the adaptation, the participants were given the following instructions: the stimuli to be presented represents offensive actions of karate: the vertical position of thrusting punches (middle or upper) should be judged in such a way that it would be middle if thrusting punch would come straight or downward, it would be upper otherwise: the direction of kicks should be judged upper if the kicking foot would come above the opponent head, it should be judged middle otherwise. Then the participants were given

about 10 practice trials each with stimuli consisting of 4 points and 19 points, in order to be familiarized with the stimuli and task to be used in this experiment. In each trial, a fixation point was presented at the center of the screen for 1000ms, followed by the stimulus presentation. When the stimulus disappeared, a dialog box listing 8 possible types of offensive actions (combination of kick/punch, left/right, upper/middle) was displayed on the screen. The participants identified the action of the stimulus with one of the 8 types and clicked a corresponding button by a mouse. The next trial then started.

After practice, the experimental sessions were started. There were a total of 16 experimental sessions, two sessions each for the 8 presentation conditions (4, 6, 8, 10, 12, 14, 16, 19 points). One session consisted of 50 trials, and single presentations of 100 stimuli were chosen randomly across two sessions for each presentation condition. The sixteen sessions were divided into two series of 8 sessions for different number of points, and each series were run in a random order. The participants were allowed to take rests between the sessions for as long as they wish.

Data Analysis. Two kinds of proportion of correct identification, namely complete PC and partial PC, were computed from the data of individual participants. Complete PC was the proportion of correct identification with 8 alternatives: the responses were counted as correct when they matched all three attribute of the presented stimulus (kick/punch, left/right, upper/middle). Partial PC was the proportion of correct for 4 alternatives, or combination of kick/punch and left/right, irrespective of vertical position (upper/middle).

Results and Discussion

Figure 1 shows the means of the complete PC and partial PC of all the participants. It can be seen in the figure that the complete PC monotonically increased with the number of presented points, with a steeper increase for 8 to 12 points. The partial PC were higher and increased more gradually than the complete PC, and it leveled off for more than 10 points.

The results suggest that the participants perceived offensive actions of karate reasonably well when the stimuli consisted of 10 points or more. The complete PC for 10 points was 75.45%, roughly at the middle of 50 and 100%. The corresponding partial correct was 96%, indicating that identification of kick/punch and left/right was almost perfect. When the stimuli consisted of only four points, the complete PC was much higher than chance (12.5%), probably because of even distribution of points over the body and the instruction given to the participants that the stimuli represent karate offensive actions. Since the partial PC for 4 points was more than 80%, it is likely that these two factors contributed to good identification of offensive actions. A steeper increase in complete PC from 8 to 12 points is probably due to the fact that there were two points or more in each of 5 body areas (see Apparatus and stimuli) when the number of total points in the stimuli was more than 8. The points closely presented to each other are likely to be perceptually connected and would lead to a clear image of body motion.

Experiment 2

Method

The 20 participants of Experiment 1 also participated in Experiment 2. The apparatus was identical to Experiment 1. The stimuli were identical to the 10 point stimuli in Experiment 1, except that their presentation was cut off at the frame corresponding to either 1/6, 2/6, 3/6, 4/6, 5/6 or 6/6 (full presentation) of the duration of their full presentation. Twelve sessions were run separately and twice for each of the 6 different presentation durations. Those sessions

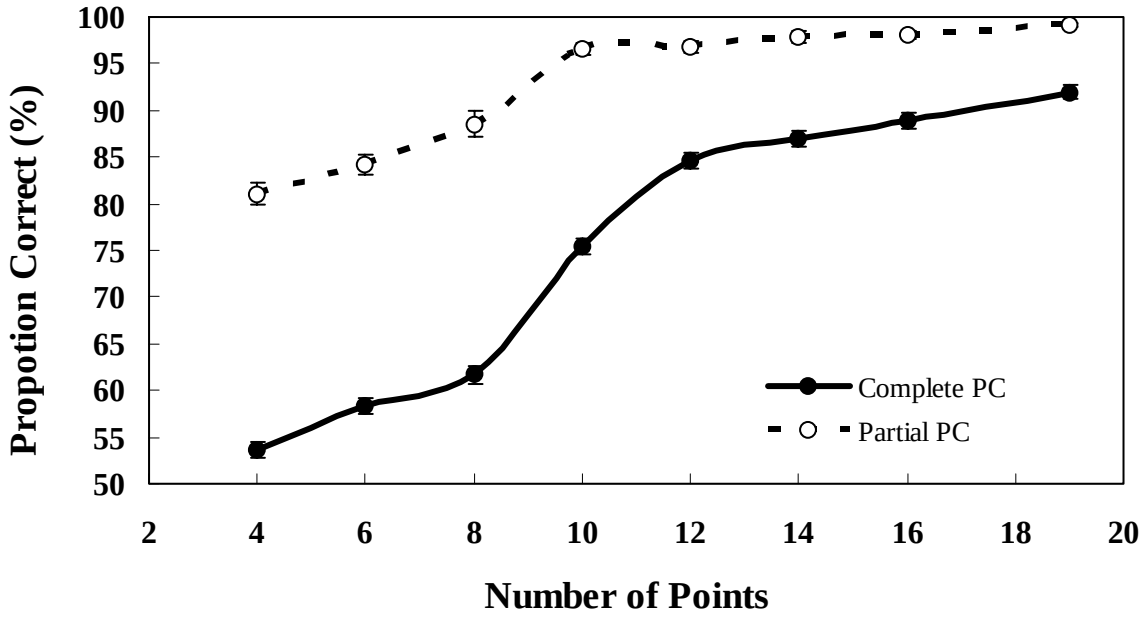

Figure1. Mean complete PC and partial PC of 20 participants, as a function of number of points constituting biological motion stimuli. Vertical bars indicate standard errors of the mean.

were divided into two series of 6 sessions for the different durations and were conducted in a random order. In all other respects, the procedure were identical to that of Experiment 1.

Results and Discussion

Figure 2 shows the mean proportions of correct identification of 20 participants, along with the proportion correct that were computed for the stimuli representing punches only and those representing kicks only. They increased linearly with the presentation duration, with some noticeable differences between kicks and punches. ANOVA revealed no significant difference between them, but a significant main effect of presentation duration ($F(5,95) = 256.0$, $p < .01$) and a significant interaction between the duration and the kick-punch difference ($F(5,95) = 8.22$, $p < 0.01$). In 6/6 condition, the proportion correct was equivalent to that obtained in Experiment 1 with the stimuli consisting of 10 points.

The linear increase of proportion correct with presentation duration seems to indicate that the observer's recognition of karate action depends solely on the amount of kinetic information contained in the motion of point-lights that increases in presentation duration. It should be also noted that the standard errors (indicated by error bars) were larger than those of Experiment 1, which suggests that the stimuli and the task of this experiment reflect individual difference in recognition of karate action.

General Discussion

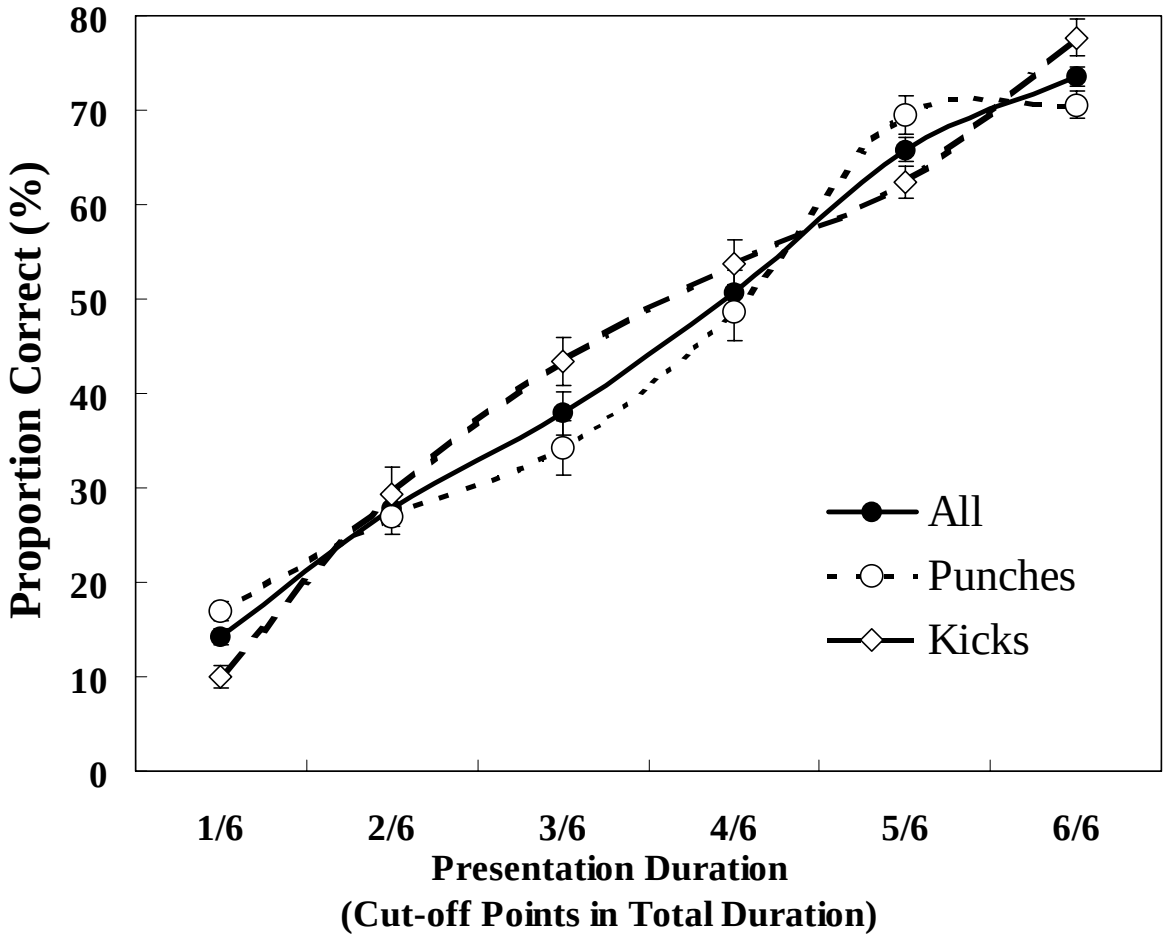

Figure2. Mean PCs of 20 participants for all stimuli, punches only, and kicks only, as a function of presentation duration (cut-out points in total duration). Vertical bars indicate standard errors of the mean.

The present study investigated spatio-temporal characteristics of perception of karate offensive actions, using biological motion. Experiment 1 showed that accurate recognition of offensive actions was possible even with a small number of point-lights. This may be due to prior knowledge of karate actions and the even distribution of point-lights over the body.

Experiment 2 showed that accuracy of perception increased linearly with the temporal information of karate actions. Individual differences, shown by the standard error, was larger in Experiment 2 than in Experiment 1. This may imply that the temporal occlusion methods used in Experiment 2 may reveal more clearly individual difference in perception, such as expert-novice difference. Research comparing Karate athletes with non-athletes in similar experiments is necessary and remains to be done. The results of those two experiments indicate that recognition of attack motion from point-light stimuli reflected spatio-temporal information in the stimuli, with little influence of anticipation from earlier motion.

Acknowledgments

The research was supported by Grants-in-Aid for Scientific Research 17530528 to S.M. and 19103003 to Yoshitaka Nakajima, and by Grant-in-Aid for the 21st Century COE Program. We thank Dr. Willy Wong for reading this manuscript and providing editorial suggestions.

References

Abernethy, B. (1990). Anticipation in squash: Differences in advance cue utilization between expert and novice players. *Journal of Sports Science, 8*. 17-34.

Abernethy, B., & Russell, D. G. (1987). Expert-novice differences in an applied selective attention task. *Journal of Sport Psychology, 9*, 326-345.

Mori, S., Ohtani, Y., & Imanaka, K. (2002). Reaction times and anticipatory skills of karate athletes. *Human Movement Science, 21*, 213-230.

Seya, Y., & Mori, S. (2007). Motion illusion reveals fixation stability of karate athletes. *Visual Cognition*,15. 491-512.

Williams, A. M., Davids, K., & Williams, J. G. (1999). *Visual perception and action in sport.* London：E & FN spon.

Williams, A. M., & Elliott, D. (1999). Anxiety, expertise, and visual search strategy in karate. *Journal of Sport & Exercise Psychology, 21*, 362-375.