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THE ROLE OF VISUAL PERCEPTION IN ACTION ANTICIPATION IN BASKETBALL ATHLETES

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Abstract—Athletes exhibit better anticipation abilities than novices. However, it is not known whether this difference is related to different visual perceptions between them and which neural elements are involved in producing this difference. Fifteen elite basketball players and 15 novices participated in an action anticipation task with basketball free throw. Accurate rate for anticipation and gaze behavior were analyzed. Functional brain activity was recorded using functional magnetic resonance imaging. We found that the accurate rate for anticipation was higher in athletes than that in novices. Athletes showed more stable gaze fixation than novices and the locus of fixation was reliable in athletes but not in novices. Athletes showed higher activity in inferior parietal lobule and inferior frontal gyrus than novices during action anticipation. We conclude that the processes for action anticipation in elite athletes and novices are different and this difference is caused by different visual perceptions between them.

Key words: athlete, action anticipation, basketball, mirror neuron system, visual perception.

INTRODUCTION

Behavioral studies show that elite athletes exhibit high execution accuracy and excellent performance in anticipation of rapid and complex motor tasks. In particular, elite athletes are able to make decisions within limited time when the game is in progress (Allard et al., 1980; Starkes and Allard, 1983; Starkes, 1987; Bard and Goulet, 1994; Williams et al., 1999). Action anticipation is highly relevant to motor skills. Experts display better action anticipation compared to novices in a variety of sports such as badminton (Abernethy and Russell, 1987a,b; Jin et al., 2011), snooker (Abernethy et al., 1994), baseball (Paul and Glencross, 1997), softball (Molstad et al., 1994), basketball (Tenenbaum et al., 1999), cricket (Houlston and Lowes, 1993; McRobert et al., 2007), soccer (Roca et al., 2011), tennis (Smeeton and Huys, 2011) and volleyball (Cañal-Bruland et al., 2011). The difference between elite athletes and novices in action anticipation may be resulted from better visual perception in elite athletes compared to novices. Visual perception is an active process of locating and extracting visual information from the environment and integrating them with other sensory inputs. In addition, various cognitive factors including past experience, motivation and development are involved in incorporating all the integrated information in visual perception. Previous studies revealed that the methods elite athletes and novices used to extract visual information for anticipation are different (Abernethy, 1990a,b, 1991; Williams and Davids, 1998; Abernethy et al., 2005) and that elite athletes might extract kinematic information of observed domain-specific actions to predict their future course more efficiently than novices (Ward and Williams, 2003; Overney et al., 2008). In this regard, many studies focused on the different contribution of motor and visual expertise in the perceptual advantage of elite athletes. Aglioti et al. (2008) reported that the superior performance of basketball players in anticipating the outcome of a free throw might rely on reading the body kinematics. Study performed in volleyball supporters found that only supporters trained with a physical practice course but not those trained with an observational practice course showed improved ability to predict the fate of the actions by reading body kinematics, suggesting that visual perception is important in predicting others' action but direct motor experience is required in such a high cognitive function (Urgesi et al., 2012). Study from the same group discussed these two components further and reported the possibility that visual perception rather than motor ability might play a central role in extracting kinematic information as they found that elite kickers were more often fooled by the incongruent actions performed in penalty kick compared to goalkeepers or even novices (Tomeo et al., 2012). However, it is still not clear how visual perception is involved in the anticipation of a motor task and what the underlying neural elements are as it is applied to the functional activity in the related brain areas.

Inferior parietal lobule (IPL) has strong functional connectivity with multiple brain areas and is involved in complex cortical functions including spatial perception

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Abbreviations: ANOVA, analysis of variance; EPI, echo-planar imaging; fMRI, functional magnetic resonance imaging; IFG, inferior frontal gyrus; IPL, inferior parietal lobule.

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and visuomotor integration. Evidence from both lesion and electrophysiological studies suggests that the IPL is important for behavior relevant to the visual perception (Anderson, 2011). Inferior frontal gyrus (IFG) is typically implicated in decision making and is important for semantic working memory (Buckner, 1996). On the other hand, activation of mirror neuron system in the premotor and parietal cortex in monkeys can be recorded both during the execution and the observation of a given motor task (di Pellegrino et al., 1992; Gallese et al., 1996; Rizzolatti et al., 2001; Fogassi et al., 2005). Functional magnetic resonance imaging (*f*MRI) studies in humans reported similar results that brain areas thought to be part of the mirror neuron system are activated both in execution of action and during observation and understanding of the motor task performed by a third-person (Calvo-Merino et al., 2005, 2006; Tkach et al., 2007). In particular, the fronto-parietal action observation network (namely IFG and IPL) is considered the fundamental neural element for the ability of action anticipation, which is highly related to mirror neuron systems (Abreu et al., 2012). We hypothesized that the processes for action anticipation of an experience-related motor task in elite athletes and novices are different and that this difference is caused by different visual perception between two groups. Our hypothesis may also predict that IPL and IFG (related to mirror neuron systems) will show more functional activity in the athletes than novices during this process of action anticipation.

EXPERIMENTAL PROCEDURES

Participants

Fifteen basketball players (mean age 19.6 ± 1.3 years, age range 18–21 years) and 15 age-matched novices (mean age, 19.3 ± 1.3 years, age range 17–21 years) participated in the study. All participants were right-handed (Bryden, 1977) males. The basketball players were national second-level athletes, recruited from the basketball team of Shanghai University of Sport; they were trained 7 ± 1.7 h per week for 3–10 years (mean duration, 6.4 ± 1.9 years). Novices had experience in watching basketball matches and understood the basic rules in basketball. However, none of them had experience in professional training in basketball or any other sports. All participants had normal or corrected-to-normal visual acuity in both eyes and were naive about the purposes of the experiment. The procedures, approved by the local ethics committee, were in accordance with the ethical standards of the 1964 Declaration of Helsinki. Participants gave their written informed consent prior to the experiment.

Experimental stimulation

A set of 11 color pictures (Fig. 1) of free basket shots recorded by a high-speed digital camera (Canon 5D MAXIII, Canon, Japan) at a speed of 7 pictures per second were used as experimental stimulations for the study. The movements were performed by male professional basketball players, who did not know the purpose of the study. The duration of each free throw was about 1.6 s. Forty groups of consecutive pictures were chosen for the experimental stimulations. In 20 groups of pictures the ball landed in the basket (IN) and in the other 20 groups the ball landed out of the basket (OUT). The time course of the movement was divided into three different phases: phase 1, the basketball left the model player's hand; phase 2, the basketball reached climax of its trajectory; phase 3, the basketball approached the basket. Each phase was composed of three pictures. The last two pictures (pictures 10 and 11) were excluded from the experimental stimulations. We predicted that the brain activity and eye movement would be different in these three phases as different completion of information was presented to the participants. Three experimental conditions were performed with different numbers of pictures (condition 1: first 3 pictures; condition 2: first 6 pictures; condition 3: first 9 pictures) (Fig. 1). It should be noted that we used continuous pictures rather than video as the experimental stimulation since the selected pictures provided important information (for anticipation of IN or OUT) more stably than video. The exposure time for each picture was 143 ms, same as the time for taking the pictures (7 pictures per second). Two example experimental stimuli with ball IN and OUT shot were attached as a Supplementary material.

Behavioral study for anticipation

A block design of stimuli was used to ensure that same experimental protocol was performed in behavioral and *f*MRI studies (see next session for *f*MRI study). Fifteen blocks (5 blocks for each experimental conditions of 3, 6, 9 pictures) with eight trials in each block were performed. Two sessions of behavioral and *f*MRI studies were performed on different days. The order of two sessions for each subject, the order of 15 blocks in each session and the order of trials with ball IN vs. OUT in each block were randomly presented. The participants were notified of the type of experimental stimulations (3, 6, 9 pictures) before each block. One hundred and twenty trials (15 blocks × 8 trials) with 20 trials of ball IN and OUT stimulations in each experimental conditions (3, 6, 9 pictures) were performed. The experimental stimulation was followed by a 3 s control stimulation (still image). The last picture in the set of 11 pictures for IN shot (Fig. 1A, picture 11) was used as a still image. The still image included the player and environment, similar to the pictures used for experimental stimulations. We set a 3 s inter-trial interval between the experimental and control stimulations. Participants were required to predict the outcome of the shot with ''Ball in'', ''Ball out'' or ''I don't know'' in the inter-trial interval by pressing the response button after the last picture was presented. Three buttons represented three different responses and the participant used one of three fingers (index, middle, ring) of the right hand to press the different buttons. The button press was recorded by E-prime V1.1 software (Psychology Software Tools, Inc., Pittsburgh, PA, USA).

Results for behavioral study for anticipation were evaluated with the accurate rate of prediction. The rate was calculated as the percentage of the correct responses (IN responses for IN shots and OUT responses for OUT shots) and incorrect responses (OUT responses for IN shots and IN responses for OUT shots) to the number of total trials. In addition, the rate of uncertain responses (response ''I don't know'') served as an index of the criterion used by the participants during anticipation. A two-way repeated measures analysis of variance (ANOVA) was used to test whether the accurate rate in anticipation was different under various conditions. The experimental condition (3 pictures, 6 pictures, 9 pictures) was the within-subject factor (repeated measure) and group (athlete vs. novice) was the between-subject factor. *Post hoc* unpaired *t*-test with Bonferroni's correction was used to examine at which experimental conditions athletes were different from novices if ANOVA showed a significant interaction. The threshold for significance was set at $p < 0.05$. In addition, a two-way repeated measures analysis of variance (ANOVA) was used to compare behavioral data obtained from *f*MRI and behavioral