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An Exploration of the Role of Social Roles and Rewards in the Monitoring of Athletes' Action Outcome

Kai Zhao[1,a,*]

[1]*Shanghai University of Sport, Shanghai, China*
[a]*zkzlzyyzye@foxmail.com*
[*]*Corresponding author*

Abstract: *After years of a dedicated training life, athletes accumulate a wealth of motor skills and knowledge in the sport to which they belong. This study reviews previous research on movement monitoring to examine the effects of social roles and rewards on athletes' movement monitoring. In the field of cognitive neuroscience, the FRN and OFRN are early components of action outcome monitoring, which are indicators of action outcome monitoring of self and others, while the P300 and OP300 are late components of action outcome monitoring, which are indicators of the emotional and motivational evaluation of action outcomes. The amplitude of the FRN and P300 feedback to oneself and its topography are moderated by social roles and are more responsive to teammates than to opponents. The feedback of reward information has a strong influence on the monitoring of action outcomes, as reward information influences the release of dopamine through the reward loop, which further alters the activation of the ACC, which in turn influences the FRN, thus influencing the monitoring of action outcomes for oneself or others. People can more accurately understand the movements they have mastered, i.e. the movements present in their self-motor representations, than unfamiliar movements. The brain can interpret immediate incoming sensorimotor and contextual information based on its own experience, and anticipate the outcome of others' movements, or understand the intentions implied in the movements.The impact of rewards on outcome monitoring is greater for athletes than for the general population in terms of processing more information about gains and losses than about gains and losses; social roles (self, teammates, opponents) and rewards (morerewards, less rewards, more penalties, less penalties) affect athletes' outcome monitoring, in terms of processing more information about gains and losses of self and teammates than about gains and losses of opponents.*

Keywords: *Roles, Opponents, Teammates, Rewards, ERP, FMRI*

1. Introduction

Rabbitt argues that monitoring one's own behaviour is the basis for successfully adapting subsequent behaviour, as well as learning and guiding future actions[1]. In sport, athletes need to monitor their own behaviour at all times during training and competition in order to behave correctly, and Festinger suggests that monitoring one's own behaviour may be more salient in the presence of others [2]. Athletes will always pay attention to the actions of others during competition, especially when they are related to their own goals, for example: their teammates or opponents.

FRN and OFRN are early components of action outcome monitoring, indicators of action outcome monitoring of oneself and others, whereas P300 and OP300 are late components of action outcome monitoring, indicators of emotional and motivational evaluations of action outcomes [3,4], and Generally pecuniary benefit feedback triggers a greater P300 component compared to outcome evaluations of losses[5].

According to reinforcement learning theory, the monitoring of action outcomes in group sports programs relies on external feedback information, and the monitoring system transmits the reward and punishment information (TD) from the FRN, P300, to the ACC, the core brain region of cognitive monitoring, which adjusts behaviour in response to the reward information [6,7,8].

The amplitude of FRN and P300 feedback to oneself and its topography are moderated by social roles and are more responsive to teammates than opponents. The relationship between others and

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themselves also affects their own movement outcome monitoring. Athletes in team sports also have an important influence on teammates' and opponents' movement outcome monitoring during competition, as does the feedback of reward information to teammates and opponents.

Also, during sporting competitions, athletes are constantly confronted with the situation of whether to score or lose points, and how many points are scored and lost. To win successfully, athletes must constantly monitor their own behaviour, as well as that of their teammates and opponents, in order to determine whether their behaviour is meeting the requirements of the task. Numerous studies have shown that reward, as an external stimulus trigger, can enhance cognitive control by inducing specific emotions and motivations [9,10,11], i.e., individuals can effectively suppress distracting stimuli compared to unrewarded stimuli, and increase cognitive control of reward-related stimuli. Interference from distracting stimuli compared to non-rewarding stimuli, increasing the response to reward-related stimuli[12,13,14,15] .

In summary, the scientific question of this study is posed, how do social roles (self, teammates, opponents) and rewards (more rewards, less rewards, more penalties, less penalties) affect the monitoring of athletes' movement outcomes?

2. Review of Literature

2.1 The Concept of Action Outcome Monitoring

In everyday life, people use external feedback stimuli to obtain information about the appropriateness or correctness of their behavioural responses. Only when people receive feedback about the results of their behaviour and the mistakes they have made are they likely to change their behaviour accordingly in order to achieve their original goals. When people realise that their behaviour is off target, they take other measures to compensate, mainly through immediately corrected correct behaviour and cognitively influenced strategy changes or task resets. This process of quickly and accurately evaluating the pros and cons of one's actions, right and wrong, and adjusting one's behaviour after making one's own decisions is known as outcome monitoring[16]. In order to build a sense of autonomy and ensure meaningful interaction with the external world, we must understand the relationship between our actions and their outcomes, a process known as motor outcome monitoring. Research on motor control has proposed positive model theory as a potential mechanism which proposes that we make predictions about the sensory outcomes of our actions[17,18].

2.2 Neural Mechanisms of Action Outcome Monitoring

Feedback-related negativity (FRN; also known as medial frontal negativity, or MFN) is a negative-trending wave in event-related potentials, where negative feedback is generated 200-300 ms after feedback presentation compared to positive feedback. It is time-locked to the feedback cue. Its source is localised near the anterior cingulate cortex (ACC), arising in the prefrontal region of the brain [19]. Some researchers have suggested that the FRN reflects the process of evaluating the emotionally motivated meaning of feedback stimuli [20], but others have suggested that the FRN may reflect the brain's conflict monitoring processes[21].

The oFRN has the same time window as the FRN (generated 200-300 ms after feedback presentation), but the wave amplitude of the oFRN is smaller than that of the FRNs [22,23,24].

The P300 is a positively oriented wave that appears in the postcentral brain region approximately 300-600 ms after the presentation of a feedback stimulus[25], and is associated with the allocation of attentional resources in decision-making or outcome evaluation [26] and high levels of motivation/emotion evaluation [27,28,29].

The OP300 shares the same time window as the FRN (approximately 300-600 ms after the feedback stimulus is presented), and responses may also be related to higher-order outcome evaluations and the emotional significance of the feedback, being sensitive to the size of the reward and the degree of deviation from the expected and actual outcome[30,31,32].

2.3 Reinforcement of Learning Theory and Monitoring of Action Outcome

Reinforcement learning theory (RLT) is based on computational models and Watson's law ofeffects, which states that response outcomes provide cognitive control The monitoring system adjusts

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behaviour in response to the learning signal[33,34].

The theoretical model of reinforcement learning consists of two parts: the task module, which is responsible for stimulus-response mapping and generating response outputs; and the monitoring module, which evaluates the response outputs in the task module, reinforcing good behaviour and punishing bad behaviour. The task module consists of four layers: the perceptual layer, which encodes external stimuli; the categorisation layer, which differentiates between stimuli, targets and non-targets; the response layer, which produces specific responses, i.e. executes the stimulus-response mapping; and the attention layer, which increases the activation of targets in the perceptual layer, suppresses non-target activation and determines the response bias, i.e. directly activates a response in the response layer. The monitoring module consists of three layers: a state layer, which characterises the target stimulus, the response, and the stimulus-response connection, and receives feedback on the stimulus; a numerical layer, which calculates the probability of success or failure for this trial; and a TD (temporal difference error) layer, which calculates the TD signal[35,36]. TD is a concept specific to reinforcement learning theory and is computed through an "adaptive critic", reflecting the assessment of the current system state. The TD signal is transmitted through the midbrain dopamine (DA) system to the ACC, which in turn monitors and modulates a series of motor controllers to regulate subsequent behaviour. When an incorrect response occurs, the system detects that the current behaviour is worse than expected resulting in a decrease in midbrain dopamine activity and a consequent decrease in the amount of dopamine input to the ACC, while a correct response increases the activity of the dopamine system.

The midbrain dopamine system plays a crucial role in reinforcement learning [37], as dopamine carries a feedback signal to de-inhibit motor neurons in the ACC. It has been found that FRN amplitude increases significantly after dopamine-promoting amphetamine injections[38,39], but decreases significantly after ingesting alcohol that affects dopamine receptors [40]. This suggests that dopamine, a neurotransmitter, has an important influence on the production of FRN.

Thus, we hypothesized that feedback of reward information has a strong influence on the monitoring of action outcomes, with reward information influencing the release of dopamine through the reward loop, which further alters the activation of the ACC, which in turn influences the FRN, thus influencing the monitoring of action outcomes for oneself or others. Furthermore, the amplitude of FRN and P300 feedback to self and its topography are modulated by social roles and are more responsive to teammates than to opponents. The relationship between others and oneself also influences one's own movement outcome monitoring, and the feedback of reward information has an important effect on the movement outcome monitoring of teammates and opponents in team sports athletes, with respect to both teammates and opponents, during competition.

3. Social Roles

3.1 The Concept of Social Roles

A social role is a set of norms and behavioural patterns of rights and obligations that correspond to a certain social status or identity of people.

Social roles include three main meanings; social roles are a set of social patterns of behaviour; social roles are determined by a person's social status and identity and are not self-determined; social roles are in line with social expectations (social norms , responsibilities, and obligations etc.). Therefore, for any kind of role behaviour, as long as it meets the three characteristics mentioned above, it can be considered a social role.

In this article we have divided social roles into three categories, self, opponent and teammate.

3.2 Social Roles and Action Outcome Monitoring

In gaming tasks, oFRN is greater when participants perceive that they are observing other people rather than the computer [41,42]. Given previous evidence, it is suggested that the observation effect depends on the relationship of the observed object to itself [43].

The amplitude of FRN and P300 feedback to oneself and its topography are modulated by social roles and are greater for teammates than for opponents. It has been shown that for feedback on one's own actions, cooperation (but not competition) can increase the social pressure to behave and that the

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FRN is greater and the teammate OFRN is also increased [44,45].

The affective evaluation of feedback may depend on contextual factors such as the social situation: receiving negative feedback in the presence of others may enhance its impact compared to feedback provided to oneself.

4. Rewards

4.1 The Concept of Reward

The reward process in the brain is an iterative learning process that includes goal-directed behaviour and adaptive behaviour in response to stimuli. By nature, rewards that have a positive effect on an organism's survival (e.g. sex, food) are referred to as intrinsic or primary rewards; rewards that are learned through association are referred to as extrinsic or secondary rewards (e.g. money).

The rewards we use in this article are extrinsic rewards.

4.2 Reward and action result monitoring

The amount and potency of a reward are processed separately in the brain. Furthermore, this separation appears to occur early in processing, with the FRN being sensitive to the potency processing of the reward and the P300 being sensitive to the size of the reward [46].

Since the validity and the amount of reward are separated, this study has done the two reward dimensions separately.

5. Sporting Experience

Matthews points out that there are three kinds of experience acquired through the body that make up the content of consciousness: first, self-experience. Self-experience is not a purely conscious experience beyond the body, but an ontological experience of the body's position, state, movement, purpose, needs and desires. Secondly, the experience of the object. This experience is based on bodily perception, and the meaning of the object is also produced through the bodily experience of the object. Again, the experience of others as intentional subjects[47]. This experience we have of others is also based on bodily perception and is a bodily experience.

Physical experience is experience gained through the body, both physical experience gained with one's own body and experience gained only through the bodies of others, and then motor experience is experience gained through physical movement. For the individual, reading a verb or a sentence containing a verb is not only a semantic process, but also an experience of bodily movement. In the same way that athletes often use their bodies to perform difficult movements is a cumulative experience of movement.

Depending on the characteristics of the sporting group, sports can also be divided into team sports, which are sports played by many people, and non-team sports, which are sports played by individuals.

It has been suggested that there are types of movement: Open skills, where the individual cannot anticipate the next change, and Close skills, where the individual knows what is going to happen next.

There are also types of movement that can be classified as high perceptual load movements with high cognitive involvement (e.g. basketball) and as low perceptual load movements with low cognitive involvement (e.g. gym), in terms of the degree of cognitive involvement during movement. There is also a distinction between Self-paced and Externally-paced movement types based on the planned and sudden nature of the movement. Self-paced exercise(Self-paced allows the athlete to plan in advance for the timing of important and critical movement steps, and also allows the athlete to plan and control the pace of their movement as they complete the movement. Externally-paced teammates, on the other hand, do not have the time to plan in advance for the athlete to respond as quickly as possible to unexpected external stimuli and to make quick decisions.

5.1 Movement Experience and Social Roles

Based on the fact that there are three social roles in team sports - self, teammates and opponents -

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and that in open sports athletes rely more on external feedback for information about movement outcomes, according to the reinforcement learning theory model, then athletes in open sports in team sports process more information about movement outcomes. Just for example, athletes in basketball, volleyball and football.

5.2 Sport Experience and Rewards

Ames classifies reward structures into three types: competitive, cooperative and individualised structures, and has shown through extensive research that the environment is most widely characterised by reward structures, and Ames argues that people perform differently on target task completion within different reward structures.

An individual's chances of being rewarded depend not only on their own efforts but also on the efforts of other members of their group [48].

Research on the effects of cooperative and competitive cooperation structures on manipulative skills has shown that manipulative performance is significantly better under a competitive structure than under a cooperative structure. Under the competitive structure, there is a greater sense of purpose and direction in the joint activities between individuals, an increased urgency to cooperate in order to compete with other groups, an increased cohesion between the two individuals, so that the relationship between the collaborators becomes closer, the work of the two individuals is mutually supportive, there is timely communication during practice , there is mutual understanding and cooperation during competition, self-esteem is maintained as neither has to take full responsibility, and This results in better operational performance than would normally be the case in a collaborative situation.

5.3 Movement Experience and Monitoring of Movement Results

People can understand the movements they have mastered more accurately than unfamiliar movements, i.e. the movements that exist in the self-movement action in the motor representations. The brain can respond to immediate incoming sensorimotor information and context based on its own experience Information is interpreted and the outcome of another person's action is predicted or the intention implied in the action is understood.

Therefore, this ability to process movements grows with motor experience.

6. Conclusion

The effect of reward on movement outcome monitoring was greater in athletes than in the general population when processing more information about gains and losses compared to more information about gains and losses; social roles (self, teammates, opponents) and rewards (more rewards, less rewards, more penalties, less penalties) influenced athletes' movement outcome monitoring, and the effect of processing more information about gains and losses in self and teammates compared to more information about gains and losses in opponents had a greater effect on movement outcome monitoring. In addition, the functional brain connections between the athletes' teammates were higher than those of their opponents.

7. Limitations of Current Research and Future Research Perspectives

Firstly, research into the role of reward and punishment information in the monitoring of action outcomes is still confined to studies of ordinary people, whereas athletes are also constantly faced with situations during sporting competitions in which athletes score or lose points, and how many points they score and lose. To win successfully, athletes must constantly monitor their own behaviour, as well as that of their teammates and opponents, to determine whether their behaviour is meeting the requirements of the task. Numerous studies have shown that reward, as an external stimulus trigger, can enhance cognitive control by inducing specific emotions and motivations[49], i.e., individuals can effectively suppress distracting stimuli compared to unrewarded stimuli, and increase cognitive control of reward-related stimuli. Interference from distracting stimuli compared to non-rewarding stimuli, increasing the response to reward-related stimuli [50, 51, 52]. Further research is then necessary for this group of athletes in terms of reward information influencing the monitoring of movement outcomes.

Secondly, when athletes, especially those in team sports, are in competition, athletes are constantly

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aware of other people's movements during competition, especially when they are related to their own goals, e.g., their own teammates or opponents. It has been shown that the observation effect of action outcome monitoring depends on the relationship of the observed object to oneself. In addition, watching an opponent lose stimulates a greater FRN amplitude than watching an opponent win, and this FRN difference does not exist when watching an opponent. Furthermore, processing of action outcome monitoring (FRN, P300) is positively related to the personal traits of empathy and perspective-taking ability, but negatively related to aggression. This researcher selected 71 athletes and 91 generalists at the Shanghai Sports Institute and conducted independent sample t-tests on empathy, perspective-taking ability, and aggression, respectively, and found highly significant differences between athletes compared to generalists on empathy and perspective-taking ability, with athletes being higher than generalists. The difference in aggression was found to be highly significant for athletes compared to the general population, and higher for the general population than for athletes. Combining these two points, how do social roles and rewards influence how they affect athletes' monitoring of movement outcomes?

Finally, according to reinforcement learning theory, the monitoring of action outcomes in group sports programs relies on external feedback information, and the monitoring system transmits the reward and punishment information (TD) from the FRN, P300, to the ACC, the core brain region of cognitive monitoring, which adjusts behaviour in response to the reward information. What behavioural adjustments are made by athletes with stronger ACC activation compared to the general population, as opposed to teammates and opponents and differences in reward information?

Based on the findings and limitations of this study, this researcher believes that future research could explore the following three specific questions. What is the role of motor experience in the influence of reward information on action outcome monitoring? What role does motor experience play in social roles and rewards influencing action outcome monitoring? What effect do social roles and rewards have on behavioural adjustment following action outcome monitoring?

Hypothesis 1: Athletes have a greater impact on movement outcome monitoring for situations with more gains and losses than the average person, while there is no difference in movement outcome monitoring for situations with fewer gains and losses.

Hypothesis 2: Sport experience moderates the process by which social roles and rewards influence movement outcome monitoring, and athletes have a greater impact on movement outcome monitoring than the general population when processing more information about their own and their teammates' gains and losses compared to their opponents' gains and losses.

Hypothesis 3: There is a significant difference in the behavioural adjustment for processing more points scored by oneself and teammates compared to processing more points scored by oneself and teammates and processing points scored by opponents.

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