



# Knowing when not to swing: EEG evidence that enhanced perception–action coupling underlies baseball batter expertise



Jordan Muraskin <sup>\*</sup>, Jason Sherwin, Paul Sajda

Columbia University, New York, NY, United States

## ARTICLE INFO

### Article history:

Received 10 February 2015

Accepted 13 August 2015

Available online 20 August 2015

### Keywords:

Contingent negative variation

Electroencephalography

Perception–action coupling

Fusiform gyrus

Supplemental motor cortex

## ABSTRACT

Given a decision that requires less than half a second for evaluating the characteristics of the incoming pitch and generating a motor response, hitting a baseball potentially requires unique perception–action coupling to achieve high performance. We designed a rapid perceptual decision-making experiment modeled as a Go/No-Go task yet tailored to reflect a real scenario confronted by a baseball hitter. For groups of experts (Division I baseball players) and novices (non-players), we recorded electroencephalography (EEG) while they performed the task. We analyzed evoked EEG single-trial variability, contingent negative variation (CNV), and pre-stimulus alpha power with respect to the expert vs. novice groups. We found strong evidence for differences in inhibitory processes between the two groups, specifically differential activity in supplementary motor areas (SMA), indicative of enhanced inhibitory control in the expert (baseball player) group. We also found selective activity in the fusiform gyrus (FG) and orbital gyrus in the expert group, suggesting an enhanced perception–action coupling in baseball players that differentiates them from matched controls. In sum, our results show that EEG correlates of decision formation can be used to identify neural markers of high-performance athletes.

© 2015 Elsevier Inc. All rights reserved.

## Introduction

Deciding whether or not to swing at a baseball is a complex task where a 1/3-success rate is worth millions of dollars a year and a likely spot in the Baseball Hall of Fame. This interceptive action under severe time constraints requires that a batter predicts the location of a 3-inch diameter ball by extracting anticipatory cues from the opponent's actions (Abernethy, 1996; Burroughs, 1984), integrating these with perceptual cues from the spin and trajectory of the ball, and finally estimating the time at which the ball will reach the plate. While accumulating and integrating this evidence, the batter is deciding on the execution or inhibition of the interceptive action (i.e., whether or not to swing).

The extreme difficulty of this task together with the skill needed to perform it at even a modest success rate has led to the hypothesis that professional baseball players have, like other high-performing athletes, developed performance improving perceptual and cognitive abilities relative to non-athletes (Miura et al., 2010; Yarrow et al., 2009).

Several studies have investigated potential neural correlates indicative of perceptual and cognitive performance enhancement specific to baseball players. For example, Radlo et al., using electroencephalography (EEG), showed that more advanced players had faster reaction times (RTs) and greater P300 latencies when classifying pitch types compared to intermediate players (Radlo et al., 2001). Other groups

have used the Go/No-Go reaction time task (Donders, 1969) to examine the neural basis of inhibition in baseball players. Kida et al. (2005) investigated the RTs of baseball players in a Go/No-Go task and found that skilled baseball players could execute the response to the Go stimulus more quickly than less skilled baseball players, tennis players, and non-athletes (Kida et al., 2005). Nakamoto and Mori repeated the Go/No-Go task to examine whether baseball players' shorter RTs were influenced by stimulus–response compatibility (SRC) effects (Nakamoto and Mori, 2008). Specifically, they found that baseball players' simple RT, i.e., reaction time when there is no perceptual decision needed, was not faster than that of matched controls, but for baseball-specific stimuli, the stimulus–response compatibility mediated a faster response time among experts. Additionally, basing their findings on previous work linking No-Go frontal P300 strength to response inhibition, they found greater P300 amplitudes in baseball players when the SRC was similar to baseball batting. More recently, the same group showed that baseball players, performing a Go/No-Go task in which the subjects needed to coincide their response to the arrival of a moving object, had larger amplitude N2s and P300s compared to controls (Nakamoto and Mori, 2012).

There also has been substantial work pointing to athletes employing “embodied cognition.” Cognition is said to be “embodied” when it acutely depends upon features of the physical body of an agent, that is, when aspects of the agent's body play a significant causal or physically constitutive role in cognitive processing. For instance, Holt and Beilock (2006) performed an experiment with two groups of athletes (ice hockey and football players) and a novice control group where

<sup>\*</sup> Corresponding author.

E-mail address: [jsm2112@columbia.edu](mailto:jsm2112@columbia.edu) (J. Muraskin).

subjects had to evaluate the plausibility of action-related sentences representative of everyday or sport-specific situations. They found that subjects responded most quickly to items that matched the sentence-implied actions for everyday and non-sport-specific actions; however, only the athletes showed faster response times for their respective sport-specific scenarios. Similar sport-specific experiments that have offered evidence of embodied cognition include golfers (Witt and Linkenauger, 2008), American football players (Witt and Dorsch, 2009), and baseball players (Witt and Proffitt, 2005). Recently, there has been empirical evidence that supports the idea that the perception of objects in the sporting environment is embodied (Gray, 2014).

Another likely difference between expert baseball players and novices is in their respective abilities for task-specific perception–action coupling. Perception–action coupling involves tightly integrating perceptual processing with action generation. It is likely linked to the development of neural substrates, which improve with training, that enable rapid and reliable predictions from incoming perceptual information. Moshe Bar’s “visual prediction theory” is consistent with perception–action coupling in the visual domain and points to specific cortical areas likely central to differentiating experts from novices. Specifically, Bar (Bar, 2009a,b; Cheung and Bar, 2012; Kveraga et al., 2011) notes the role of the orbitofrontal cortex (OFC) in multimodal associations and links this capability with heightened prediction capability in visual experts. He furthermore provides evidence that the OFC is part of a larger visual expertise network that includes the fusiform face area (FFA). Bar hypothesizes that the associations driven in part by the orbitofrontal cortex combine with the visual expertise driven in part by the FFA to produce superior prediction capabilities in visual experts. The fusiform gyrus (FG), an area that includes the FFA, is best known for its face selectivity (Grill-Spector et al., 2004; Kanwisher et al., 1997; Liu et al., 2010), although more recently, studies have shown that the FFA responds to dynamic biological motion (Peelen et al., 2006; Sokolov et al., 2012) and non-face objects, if those objects are associated with expertise (Bilalić et al., 2011; Bilalic et al., 2012; Gauthier et al., 1999; McGugin et al., 2012; Rossion et al., 2004; Tong et al., 2008; Xu, 2005), suggesting a role for FFA, and potentially OFC, in perception–action coupling for expertise-driven rapid visual decisions.

Previous studies comparing baseball players and non-players have not looked for any preparatory neural differences during the pre-stimulus interval. However, there have been many studies investigating the preparatory neural activity during the pre-shot period of shooting, archery, putting, and dart throwing. Many of these studies have focused on the spectral power (Hatfield et al., 2004), specifically the alpha band (8–12 Hz); for a review, see (Miura et al., 2010). In addition to power fluctuations in EEG oscillatory bands, the contingent negative variation (CNV), another pre-stimulus preparatory signal, has been linked to athletic skill (Hung et al., 2004). The CNV has been connected with both motor preparation and cognitive processes including attention, expectancy, motivation, and arousal (Brunia and Damen, 1988; Ikeda et al., 1996; van Boxtel and Brunia, 1994). In this study, we plan to analyze neural preparatory signals of alpha power and CNV to compare the pre-stimulus responses of the experts to the novices.

In this paper, we use high-spatial density EEG and single-trial analysis in order to capture variability within and across individuals in a way that allows us to more fully test whether cortical areas, consistent with perception–action coupling and embodied cognition, show activity that differentiates expert baseball hitters from novice controls.

We compare EEG activity measured from Division I Collegiate baseball players (experts) to a set of matched novice controls for a novel Go/No-Go task that resembles an in-game baseball-batting situation. Using simulated baseball trajectories (Sherwin et al., 2012), we designed an experiment to match the fraction of a second a batter has to recognize the pitch “type” and decide whether or not to “swing,” given his “target” pitch. In the experiment, target pitches are cues presented to the subject prior to the pitch, indicating the type of pitch that should elicit a “Go” response. This mirrors the in-game situation

of a batter “sitting on a pitch.” A mismatch between the player’s target pitch and the resulting pitch can lead to no swing, a late swing on faster than expected pitches, or an early swing on slower than expected pitches. Fig. 1 illustrates the paradigm.

## Methods

### Subjects

A total of 19 subjects, 9 collegiate Division I baseball players (mean age,  $19.9 \pm 1.1$  years) and 10 non-player novices (mean age,  $21.2 \pm 1.6$  years), participated in the experiment. None of the novice subjects had any collegiate baseball experience. All of the expert baseball players were active players on a collegiate baseball team. All subjects reported normal or corrected vision and no history of neurological problems. All novices were right handed, while one of the baseball players was left-handed. Informed consent was obtained from all participants in accordance with the guidelines and approval of the Columbia University Institutional Review Board.

### Stimuli overview

Similar to our previous work (Sherwin et al., 2012), we simulated each pitch via a differential equation solver in Matlab 2010a (Mathworks, Natick, MA, USA) (see Pitch Simulations below) and presented these using PsychToolbox (Brainard, 1997). Pitches were simulated using 6-coupled differential equations (Adair, 1990; Armenti, 1992):

$$\frac{dx}{dt} = v_x \quad (1)$$

$$\frac{dy}{dt} = v_y \quad (2)$$

$$\frac{dz}{dt} = v_z \quad (3)$$

$$\frac{dv_x}{dt} = F(v)v_x + B\omega(v_z \sin\theta - v_y \cos\theta) \quad (4)$$

$$\frac{dv_y}{dt} = -F(v)v_y + B\omega v_x \cos\theta \quad (5)$$

$$\frac{dv_z}{dt} = -g - F(v)v_z + B\omega v_x \sin\theta \quad (6)$$

$$F(v) = 0.0039 + \frac{0.0058}{1 + e^{\frac{(v-v_d)}{\Delta}}} \quad (7)$$

The first three equations specify the change in spatial location in each direction, which equals the velocity of the baseball. The last four equations specify the accelerations due to the drag ( $F(v)$ ), the Magnus force ( $B$ ), and the gravity ( $g$ ) acting on the baseball. After specifying the initial conditions ( $x_0, y_0, z_0, v_{x0}, v_{y0}, v_{z0}, \omega$  (rotational frequency)), the 6 ordinary differential equations were solved in MATLAB. Each of the three pitches – fastball, curveball, and slider – has well-defined initial conditions. To create each pitch, we varied the initial velocity and the rotation angle. All initial velocities were sampled from the same uniform distribution ( $78 \pm 3$  mph), although each pitch had its own rotation angle distribution (fastball ( $270^\circ \pm 5^\circ$ ), curveball ( $50^\circ \pm 5^\circ$ ), and slider ( $0^\circ \pm 5^\circ$ )). For each simulated pitch, an isoluminant green circle was plotted on a gray background for every frame of the trajectory. The size of the circle increased as it approached the viewer, so as to give the illusion of depth. When the ball crossed “home plate,” the circle disappeared.

Download English Version:

<https://daneshyari.com/en/article/6024718>

Download Persian Version:

<https://daneshyari.com/article/6024718>

[Daneshyari.com](https://daneshyari.com)