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Full Length Article

Central neuronal motor behaviour in skilled and less skilled novices – Approaching sports-specific movement techniques

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A B S T R A C T

Research on motor behavioural processes preceding voluntary movements often refers to analysing the readiness potential (RP). For this, decades of studies used laboratory setups with controlled sports-related actions. Further, recent applied approaches focus on athlete-non-athlete comparisons, omitting possible effects of training history on RP. However, RP preceding real sport-specific movements in accordance to skill acquisition remains to be elucidated.

Therefore, after familiarization 16 right-handed males with no experience in archery volunteered to perform repeated sports-specific movements, i.e. 40 arrow-releasing shots at 60 s rest on a 15 m distant standard target. Continuous, synchronised EEG and right limb EMG recordings during arrow-releasing served to detect movement onsets for RP analyses over distinct cortical motor areas. Based on attained scores on target, archery novices were, a posteriori, subdivided into a skilled and less skilled group. EMG results for mean values revealed no significant changes (all $p > 0.05$), whereas RP amplitudes and onsets differed between groups but not between motor areas. Arrow-releasing preceded larger RP amplitudes ($p < 0.05$) and later RP onsets ($p < 0.05$) in skilled compared to less skilled novices. We suggest this to reflect attentional orienting and greater effort that accompanies central neuronal preparatory states of a sports-specific movement.

1. Introduction

Encoding motor behaviour during voluntary movements is widely perceived to result, at least in part, from central neuronal modulations within the motor and sensorimotor cortex. A high temporal resolution has enforced the EEG (electroencephalography) as a method of choice to detect movement-related central neuronal processes.

In the past decades, neurophysiological and neuroimaging research addressed voluntary movements by investigating movement-related cortical potentials (MRCP), most prominently the readiness potential (RP). The RP is a negatively sloping cortical potential, setting in around 2 s prior to a voluntary movement. It is well accepted that the RP physiologically describes an increasing cortical excitability and, behaviourally, subconscious readiness to prepare and execute a forthcoming

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voluntary movement (e.g. Lang, 2003; Masaki, Takasawa, & Yamazaki, 1998; Shibasaki & Hallett, 2006 and Slobonouv, Hallett, & Newell, 2004). With this, the RP is often assessed over motor areas, including the premotor cortex (PMC), primary motor cortex (M1), somatosensory cortex (SSC) and posterior parietal cortex (PPC) (Ikeda, Luders, Burgess, & Shibasaki, 1992; Ikeda et al., 2000; Nakata, Yoshie, Miura, & Kudo, 2010 and Shibasaki et al., 1993). Appraising recent developments of EEG technology, in particular its mobile use and enhanced resistance against artifacts that may occur during moving (e.g. by using active electrodes), it is suggested to detect RP during ‘‘praxis movements" (Wheaton, Nolte, Bohlhalter, Fridman, & Hallett, 2005a and Wheaton, Nolte, Bohlhalter, Fridman, & Hallett, 2005b). To investigate praxis movements, and thus sports-specific actions, choosing calm but highly repeatable and little or not fatiguing voluntary movements that are performed in a stable posture seems appropriate (Di Russo, Pitzalis, Aprile, & Spinelli, 2005), e.g. during rifle shooting or archery that, in addition, require a bilateral performance control and, thus, muscle activation (i.e. bow-holding/stabilizing hand/arm and arrow-releasing hand/arm). However, to date RP recordings during sports-specific voluntary movements, if not linked to sports-related actions, are still exceptional cases.

From laboratory setups, a consensus on general RP components (Shibasaki, Barrett, Halliday, & Halliday, 1980a and Shibasaki, Barrett, Halliday, & Halliday, 1980b) is lined by on-going debates on factors influencing RP onset and magnitude (Shibasaki & Hallett, 2006). These factors include the precision and speed of movement performances (Masaki et al., 1998), the complexity of a movement (Benecke, Dick, Rothwell, Day, & Marsden, 1985; Kitamura, Shibasaki, & Kondo, 1993a; Kitamura, Shibasaki, Takagi, Nabeshima, & Yamaguchi, 1993b and Simonetta, Clanet, & Rascol, 1991), the motivation and effort to perform a movement (Slobonouv et al., 2004), the timing process of orienting attention towards the moment of initiating a movement (Baker, Piriyapunyaporn, & Cunnington, 2012) as well as the learning of a movement and skill acquisition (Lang, 2003 and Shibasaki & Hallett, 2006). With this, findings on RP responses are not unequivocal, in particular when comparing athletes to non-athletes or different skill levels within sports-related settings that may require different movement characteristics. For example, Hung, Spalding, Santa Maria, and Hatfield (2004) report an increase of (lateralized) RP amplitude in elite table tennis players compared to amateur players preceding movement performances of the racket hand. On the contrary, Di Russo et al. (2005) report a decrease in RP amplitude in elite rifle shooters compared to non-athletes preceding voluntary shooting-finger flexion (i.e. button pressing). Aiming to assess a more realistic sporting behaviour, further observational approaches presented sports-specific actions to elite fencing and karate athletes as well as to non-athletes that resulted in decreased RP amplitudes in athletes compared to non-athletes (Del Percio et al., 2008). Reviewing these, at least in parts, contradictory findings, Park, Fairweather, and Donaldson (2015) suggest that variations in RP could, of course, merely reflect preceding preparative differences in the sports-specific movements, in particular when the respective sport types differ in movement characteristics (e.g. table tennis vs. rifle shooting vs. fencing). To date, however, RP during real sport-specific movements, taking sports type-appropriate environments into account (e.g. shooting stand other than a laboratory chair), has not been investigated. To that effect, previous findings provide supportive and convincing evidence during movement performance for context-dependent motor behavioural processes (Bock & Hagemann, 2013 and Steinberg & Bock, 2013), which have also been detected on a central neuronal level (Steinberg & Vogt, 2015). Thus, reports from studies using laboratory setups with no direct reference to a real sports-specific movement performance leave it difficult to assess whether differences between athletes and non-athletes are related to trained expertise, skill acquisition or hereditary disposition predictive of expertise (Park et al., 2015). This is with respect to a suggested neural efficiency hypothesis, characterizing cortical functioning to achieve better performances with minimized energy consumption (Jäncke, Shah, & Peters, 2000 and Kita, Mori, & Nara, 2001). In addition to a restricted transferability from laboratory setups to real sports-specific movements, investigations on central motor behavioural processes in relation to skill acquisition during real sports-specific voluntary movements remain to be elucidated.

Therefore, the aim of this study was to examine differences of central neuronal motor behaviour between skilled and less skilled archery novices during real sport-specific movements in contrast to previously investigated laboratory-instructed movements. Time-locked EEG and discrete EMG measurements determined RP onsets and magnitudes during real sports-specific repeatable voluntary movements.

For central neuronal motor behaviour indicative of a first-time performance during real sport-specific movements (i.e. archery), it is hypothesized (1) that skilled compared to less skilled novices show reduced RP amplitude that reflect greater neural efficiency to better attain scores on target. (2) Skilled compared to less skilled novices are hypothesized to show earlier RP onset that is associated with extended movement preparation to achieve e.g. a more precise movement performance.

2. Materials and methods

2.1. Participants

In this study 16 healthy, right-handed males (29.69 ± 6.25 years, 181.63 ± 6.18 cm, 80.13 ± 10.56 kg) volunteered to participate. Participants were recruited as student and staff members from the German Sport University with no known history of neurological or musculoskeletal disorders. Being recreationally active, they considered themselves as archery novices (experience was reported as none or as rare playful acting during childhood). All participants gave written informed consent.