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Proceedings

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Motor expertise facilitates the cognitive evaluation of body postures: An ERP study

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Human complex actions such as gross, whole body movements in sports (e.g., fosbury flop in high jump) are organised according to a (biomechanically) functional structure. The whole movement can be subdivided into several functionally bound sub movements. Memory representations for such movements have been shown to reflect these sub division (so-called basic action concepts; BACs) and have been related to a cognitive ("mental") level of representation (Schack, 2004; Schack et al., 2016); see Table 1.

Table 1: *The levels of the cognitive action architecture approach (Schack et al., 2016).*

Code	*Level*	*Main function*	*Content*
IV	Mental control	Regulation	Symbols, Strategies
III	Mental representation	Representation	Basic action concepts
II	Sensorimotor representation	Representation	Perceptual representations
I	Sensorimotor control	Regulation	Motor primitives, Basic reflexes

Obviously, temporal information is critical for successful and precise movement execution and should, thus, be contained within movement memory representation as it has been shown specifically for high jump movements (Güldenpenning et al., 2013). Also, the activation of temporal order information has been suggested to be an automatic process in athletes in an evaluation task regarding body postures of high jump movements (Güldenpenning et al., 2011). As movement representations (BACs) are stored at the level of mental representations, temporal order information should affect the cognitive evaluation of body postures.

We recorded the electroencephalogram (EEG) hypothesising that temporal order information affects the level of mental representation. The P300 component of the event-related potentials (ERPs) reflect cognitive evaluations of stimuli (context updating; Donchin and Coles, 1988; Polich, 2007). Thus, we expected a P300 modulation in athletes but not in novices if participants evaluate body postures of the fosbury flop. A subliminal priming paradigm was used in which various body postures of the approach or the flight phases were shown as prime and target reflecting the natural (prospective) or the reversed (retrospective) order of the movement phases. Both groups are hypothesised to differ qualitatively in processing because only athletes have an according motor programme at their disposal.

Method

A total of 33 right-handed sport students participated voluntarily; 17 novices (25,1 yrs.; 11 female) who had no practical experience with the high jump movement (or at most minimal experiences from school lessons) and 16 athletes with a focus on tack-and-field and specific experience in high jump (22,3 yrs.; 8 female). The athletes had acquired a sufficient motor representation for the high-jump movement as evidenced by practical performance. Participants gave written informed consent, and the study adhered to the ethical standards of the latest revision of the Declaration of Helsinki (Fortaleza; WMA, 2013).

Eight photographs from a high-jump movement recording (television broadcasting from the final contest of the Olympic Games 2008 in Peking) were used as stimuli (four approach and four flight phase images). Pre- and post-masks consisted of 25 × 25 randomised cut-outs (10 × 10 pixels) of the stimulus set, generated automatically by visually scrambling versions of the stimuli. Also, distraction from the irrelevant background was reduced by blurring. Stimuli were presented centrally, subtended a visual angle of 6.5° with a size of 9.0 × 9.0 cm (250 × 250 pixels). Stimulus presentation was controlled by Presentation® (version 14.1; http://www.neurobs.com). For the full stimulus set see Güldenpenning et al. (2011).

A 2 × 2 factorial design with the factors *congruency of movement phases* (same phase vs. different phases) and *temporal order* (prospective vs. retrospective) was employed in a subliminal priming paradigm. Participants were instructed to classify the target pictures as approach or flight image as fast and as accurately as possible via external push button-responses. The response button assignment was counterbalanced across subjects.

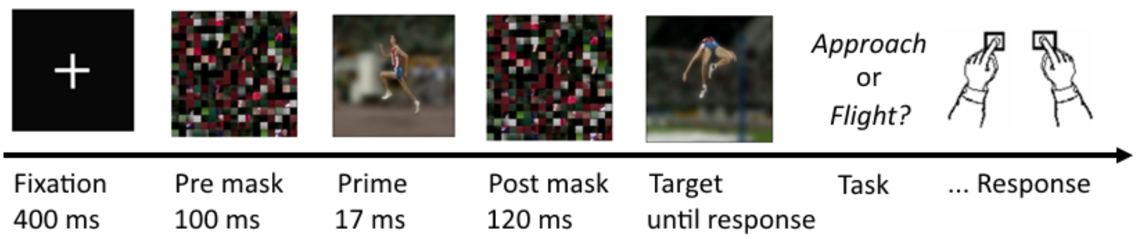

Figure 1: The trial procedure with prime and target examples. The inter trial interval was 1500 ms.

After twelve practice trials, participants performed 240 trials (24 prime target-pairs repeated ten times randomly) with a short break. For the trial timing see Figure 1. (Identical prime target pictures were excluded to avoid repetition priming.) Participants then performed a detection task on the primes (24 trials) to check the subliminal prime presentation.

The EEG was recorded (64 Ag/AgCl electrodes) based on the 10-10 system, low-pass filtered (DC-138 Hz) and sampled with 512 Hz. Eye movements were controlled for by recording the electrooculogram; impedances were kept below 5 kΩ. The EEG was band-pass filtered (0.1 - 30 Hz) and re-referenced to linked mastoids. Ocular artefacts were corrected using the Gratton algorithm. Automatic rejection was done using a moving window approach (200 ms extension; threshold ± 50 µV) and visually double-checked. The ERPs were time-locked to target onset with a 200 ms baseline before target onset. Average ERP amplitudes were calculated for each region-of-interest (ROI) and condition for the P300 time window (300-600 ms). The midline ROIs were frontal: FZ, FCZ; central: CZ, CPZ; posterior: PZ, POZ. Geenhouse-Geisser correction (ε) was applied were appropriate; corrected *p*-values, original *df* and effect size (Ω^2) are reported.

Results

Representative ERPs for both groups are shown in Figure 2. The ANOVA with the factors *temporal order, movement phase* and ROI (anterior vs. posterior, *AP*) for novices yielded no significant amplitude differences (all *F*s < 2.27; ns). The same ANOVA for the athletes yielded a main effect of temporal order ($F_{1,15}$=7.38; p<.05; Ω^2= 0.0383) which was qualified by an interaction of *temporal order* and *AP* ($F_{2,30}$=7.77; p<.01; ε=0.689 ; Ω^2= 0.0428). Separate *t*-tests for *temporal order* for frontal and central electrodes yielded no significant differences. Temporal order led to an increased P300 amplitude for prospective prime target pairs relative to retrospective picture pairs at posterior midline electrodes (t_{15}= 3.75; p<.01; Ω^2=0.1469). (Including *group* in the overall ANOVA as a between subject factor, led to a main effect of *group* ($F_{1,31}$=11.83; p<.01; Ω^2=0.0972) and an interaction of *group* and *AP* ($F_{1,62}$=4.35; p<.05; ε=0.830; Ω^2=0.00114) supporting qualitatively different processing.) Athletes' effect size for temporal order (*d*') differed from zero (0.353; posterior ROI; t_{15} = 3.75; p < .01; Ω^2=0.4011) but novices' did not (0.202; t_{16} < 1.42; ns). The peak latency did not differ among conditions (mean athletes: 442 ms; novices: 435 ms; all *F*s < 1; ns). The detection performance for primes was at chance level for novices (approach picture: 49.2 % correct; flight: 47.4 %) and athletes (approach: 48.4 %; flight 53.3 %).

Discussion

Supporting our hypothesis, *temporal order* elicited an increased P300 only in the group of athletes. The P300 amplitude was increased for prospective prime target-pairs at posterior electrodes in line with the natural order of the high jump movement (with a bilateral scalp distribution; not shown). The P300 effect suggests that the cognitive evaluation (classification) process was easier for prospective than for retrospective prime target picture pairings, possibly indicating higher response uncertainty for retrospective pairs (Horst et al., 1980). Thus, the P300 effect supports the theoretical ascription of movement representations to the level of mental representation (Schack 2004) in terms of neurophysiological processing.

Furthermore, the P300 effect was obtained with subliminal prime presentation. Hence, it is suggested that temporal order information has been processed automatically in athletes and may, therefore, be an integral part of the whole movement representation. Further research is needed to fully understand the (neurophysiological) functional relation between the mental and the action domains.

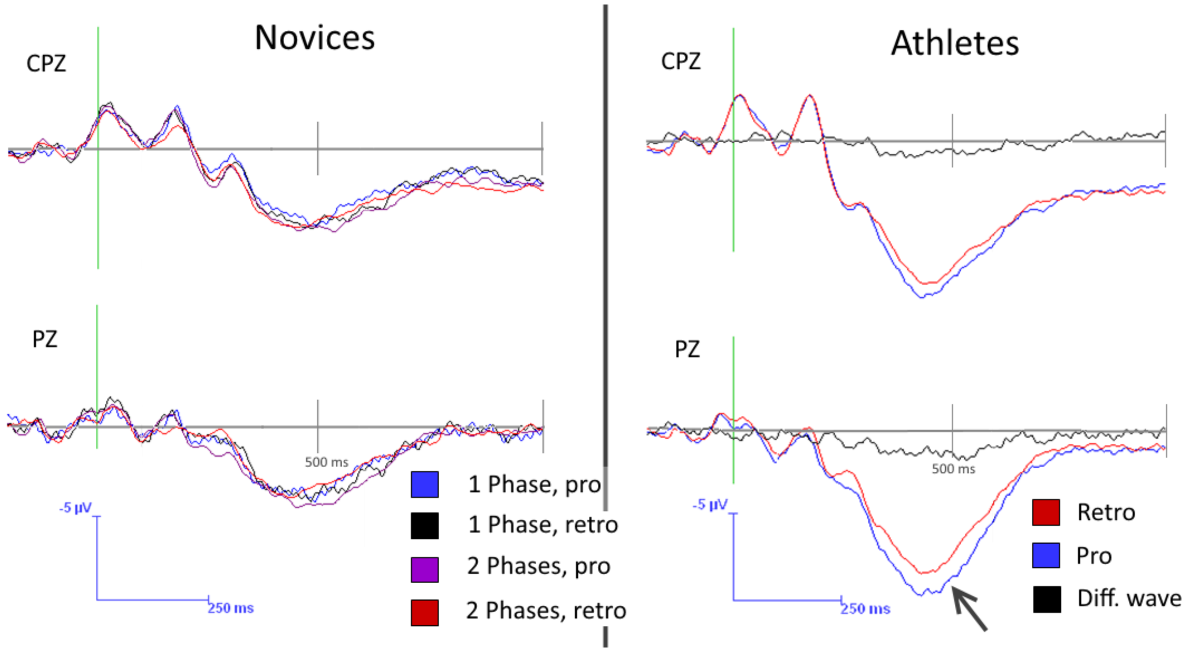

Figure 2: Grand average ERPs for novices (left panel) and athletes (right panel). Target onset at zero ms (vertical, green line; negativity up). Only athletes show an increased P300 amplitude for prospective (*Pro*) vs. retrospective conditions (*Retro*; 300-600 ms). Note, *1 Phase:* same-, *2 Phases:* different-movement phases.

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