Available online at www.sciencedirect.com
SCIENCE DIRECT®
Neuroscience Letters 384 (2005) 17–22
Neuroscience Letters
www.elsevier.com/locate/neulet

Effects of attentional strategies and anxiety constraints on perceptual-motor organisation of rhythmical arm movements

M.L.J. Court, S.J. Bennett, A.M. Williams, K. Davids *

Dunedin University, New Zealand

Received 4 January 2005; received in revised form 7 April 2005; accepted 13 April 2005

Abstract

Effects of anxiety on perceptual-motor organisation of rhythmical forearm movements were examined using an interrupted time series design with staggered baselines. Participants were exposed to repeated baseline sessions interrupted with two anxiety-inducing sessions. Results showed that under moderate levels of anxiety, determined from CSAI-2 and heart rate data, phase relations between oscillating forearms became more stable in in-phase (0°) and anti-phase (180°) modes, although these patterns were not maintained in baseline sessions following the anxiety manipulation. Data were consistent with participants employing a strategy of allocating greater attentional effort in stabilizing preferred co-ordination patterns under anxiety-inducing conditions. Results suggest that anxiety can temporarily act as a source of behavioural information, leading to the re-parameterisation of participants' intrinsic dynamics.

Keywords: Co-ordination dynamics; Bimanual co-ordination; Anxiety; Attention; Behavioural information

There has been limited research on effects of emotions on perceptual-motor organisation although some studies have shown that trait anxious individuals with high levels of state anxiety expended greater energy and displayed co-contracting neuro-muscular activation patterns [12]. However, recent studies of psychological and emotional constraints on movement co-ordination indicate that observed perceptual-motor re-organisation could exemplify functionally adaptive movement behaviours, rather than being incoherent features of action [5]. Putatively dysfunctional neuro-mechanical characteristics such as tremor and co-contractions may provide adaptive strategies for maintaining stable motor patterns under stress.

Dynamical systems theory provides a viable framework for interpreting these findings and studying interactions between cognitive, emotional and motor subsystems, incorporating tools from non-linear dynamics and synergetics to explain how order emerges in biological movement systems under constraints. The degree of order between motor system components is captured by "order parameters", variables moved through different stable and unstable states by the manipulation of "control parameters". In the co-ordination dynamics literature, an established finding is that stable phase relations between participants' oscillating limbs emerge as movement frequency changes [8]. When participants begin anti-phase oscillation of limbs, a spontaneous increase in pattern variability occurs, signalling loss of stability followed by an abrupt transition to an in-phase mode. Hallmark characteristics of dynamical movement systems, such as bi-stability, enhanced variance and phase transitions, have been observed in various tasks and successfully incorporated into models of bimanual co-ordination by Haken et al. [4].

Attempts have been made to understand how cognitive and emotional subsystems interact with motor subsystems to steer emergence of order parameter dynamics in the context of neurally specified intentions, goals, or emotional states [2]. Behavioural information arising from "specific" parametric influences on neuro-muscular systems can perturb order parameter dynamics, creating attraction toward specific co-ordination patterns, and can originate from

* Corresponding author.
E-mail address: kdavids@pooka.otago.ac.nz (K. Davids).

0304-3940/$ – see front matter © 2005 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.neulet.2005.04.036

higher order cognitive processes including attention [13], stabilizing and destabilizing intrinsically stable movement patterns. For example, when individuals need to attend to an anti-phase mode, pattern stability can increase, and transitions to an in-phase mode are delayed [10].

Of interest is whether humans can stabilize preferred modes of perceptual-motor organisation using attentional strategies when perturbed by emotional constraints. We investigated this question by examining effects of moderate levels of state anxiety on order parameter stability in a bi-manual co-ordination task. As recommended in the anxiety literature, nomothetic and ideographic methodologies were combined across a multiple-case, interrupted time series design with staggered baselines (e.g. [11]). If performers used attentional mechanisms to invest more effort in stabilizing both anti-phase and in-phase movement patterns, this strategy would be evidenced at high movement frequencies by decreased variability in both modes of co-ordination, and delays in transition from anti-phase to in-phase modes of organisation, compared to baseline. Alternatively, if anxiety-inducing conditions influenced physiological function alone, enhanced variability in both modes of co-ordination would be observed with transitions from anti-phase to in-phase modes at lower movement frequencies.

Male participants ($n = 26$) completed a modified version of the Competitive Trait Anxiety Inventory (CTAI-2) [9], which measured intensity of predisposition towards experiencing cognitive anxiety, somatic anxiety, and levels of self-confidence in socially evaluated situations. A direction scale indicated whether perceptions of intensity were debilitating or facilitating during participation in socially evaluated contexts [7]. Four right-handed participants (WB, RC, ML, DR; age range 21–23 years), with scores on the cognitive and somatic subscales above the upper 75th percentile on the intensity scales, and below the lower 25th percentile on the direction scale, volunteered for the experiment and completed consent forms. We invited individuals reporting the highest trait anxiety levels to participate in the experiment to increase the likelihood of the experimental manipulation elevating state anxiety levels.

Two custom-built manipulanda, connected to vertically mounted linear potentiometers (Spectrol, UK), provided a 220° range of motion for the bi-manual co-ordination task. Using a computer algorithm, the analogue output (kΩ) from each potentiometer was converted to absolute angular displacement values to plot the position of each manipulandum at intervals of 0.1 s (100 Hz). A visual metronome, consisting of two alternately flashing green and red circles on the left and right side of a computer screen, respectively, was presented 1.5 m away from participants at eye level. Each circle had a diameter of 80 mm and was presented for 40 ms across a range of frequencies. Electrodes placed in a lead II configuration [1] and connected to a Rigel Multicare 304 ECG (Rigel Research Ltd., England), recorded participants' heart rates. A state version of the modified Competitive State Anxiety Inventory-2 [9] provided an indication of immediate anxiety responses to task performance in socially evaluated contexts. Participants sat in a chair and grasped the manipulanda with elbows at 90° and forearms parallel to the horizontal. To maintain a fixed body position, Velcro straps were fastened around the upper body and arms as participants rhythmically oscillated forearms through pronation and supination positions and synchronized anti-phase or in-phase movements with a visual metronome. A trial commenced with a movement frequency of 0.8 Hz and one complete cycle equated to the interval between onset of two consecutive green light signals. After a plateau of eight complete cycles, stimulus frequency was increased by 0.2 Hz for a second plateau of eight cycles, a procedure repeated up to a frequency of 2.8 Hz, and then decreased at 0.2 Hz intervals back to 0.8 Hz. To ensure observation of both lights, participants visually fixated on a white marker 0.5 cm in diameter in the centre of the computer screen. As conventional in studies of co-ordination dynamics, movement patterns were allowed to emerge naturally. Participants were asked not to intentionally switch to different patterns as movement frequency increased, but to stay with the most comfortable pattern. Conventional to other studies of co-ordination dynamics (e.g., [2,8]), participants were informed that there were no criteria for 'good' or 'poor' performance with respect to a task goal or other performers, since we sought to observe intrinsically stable movement patterns, and not intentionally mediated co-ordination patterns. To determine intrinsic dynamics, participants completed five anti-phase and five in-phase trials before commencing the experiment, involving twelve sessions arranged in an interrupted time series design with staggered baselines. Ten sessions were conducted under baseline conditions with the remaining two conducted under anxiety-inducing conditions (A1 and A2) during a six-week period. The maximum time period between experimental sessions was four days. Participants completed three baseline sessions before A1 and A2, each involving ten trials performed in two blocks of five randomly ordered trials in either anti-phase or in-phase mode, with inter-trial intervals of 45 s and inter-block intervals of 2 min. A total of 120 trials were performed, 50 in each mode under baseline conditions, and 10 in each mode under anxiety-inducing conditions. Prior to testing participants rested for 15 min while their HR was measured continuously. Throughout baseline conditions participants remained alone in the laboratory, after receiving task instructions and completing the modified CSAI-2, with experimenters situated in an adjacent cubicle. At the onset of a 6-min 'anticipation period' in A1 and A2, participants were informed that senior university researchers and teaching staff would be entering the cubicle to observe performance and gain further knowledge of the experimental paradigm. During the 'anticipation period' seven observers entered the cubicle with a video camera to record forearm movements to allow analysis of movements in detail for follow-up demonstrations in lectures and conferences. As in baseline conditions, during the last minute of the 'anticipation period' participants were re-issued task instructions and required to complete the modified CSAI-2. During the 45 s