"Coping or Choking": Sustained Prefrontal Activation and Improved Laparoscopic Performance under Time Pressure

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INTRODUCTION

Unexpected intra-operative bleeding that occurs during an operation requires the surgeon to perform haemostatic manoeuvres swiftly yet accurately. However, temporal demands in the operating theatre can increase mental effort or *'cognitive workload'* resulting in physiological and psychological stress that may impair surgical performance[1-3].

Neuroimaging technology may provide the means by which cognitive workload can be measured directly. Investigators are now exploiting techniques such functional near-infrared spectroscopy to assess operator brain function during realistic surgical tasks[4-7] These studies highlight the importance of the pre-frontal cortex (PFC), an area known to be important for executive control, attention and concentration, and performance monitoring[8]. However, these studies have failed to shed light on expertise-related disparity in attention and concentration changes in and around times of temporal operative stress.

Aim: To assess the prefrontal cortical haemodynamic response in surgical traineees with varying operative experience performing a laparoscopic suturing task under time-pressured conditions.

METHODS

28 surgical trainees [15 junior trainees (ST3-4), 8 intermediate trainees (ST5-6), and 5 senior trainees (ST7+)] performed a laparoscopic suturing task under two conditions: (1) "self-paced", in which trainees were permitted to take as long as required to tie each knot, and (2) "time pressure", in which a maximum of 2 minutes were allowed. Subjective workload was quantified using the Surgical Task Load Index (SURG-TLX). A 24-channel optical topography system (ETG-4000, Hitachi Medical Corp., Japan) which measures changes in cortical haemodynamic parameters was used to infer PFC activation responses. Technical skill was assessed using task progression scores (au), error scores (mm), leak volumes (ml), and knot tensile strengths (N).

RESULTS

Subjective Workload and Motor Performance

Among junior and intermediate trainees, time pressure led to an increase in subjective workload and significant deterioration in performance. In contrast, no such change in subjective workload was observed amongst senior trainees who demonstrated less performance deterioration under time pressure (Figure 1).

Cortical Brain Function

Diminished prefrontal activation was observed among junior and intermediate trainees in the time pressure condition, relative to the self-paced condition [junior trainees: ΔHbO_2 (μM) median ± IQR (self-paced vs time pressure): 0.485 ± 1.952 vs 0.229 ± 1.846, Wilcoxon Signed Ranks $p<0.001$]; intermediate trainees [ΔHbO_2 (μM) median ± IQR (self-paced vs time pressure): 0.443 ± 2.298 vs 0.127 ± 2.192, Wilcoxon Signed Ranks $p=0.002$]. Conversely, sustained PFC activation was evident amongst senior trainees [ΔHbO_2 (μM) median ± IQR (self-paced vs time pressire): 0.918 ± 2.177 vs 0.726 ± 2.363, Wilcoxon Signed Ranks $p=0.129$] (Figure 2). Furthermore, time pressure led a reduction in size of the spatially distributed network of activated channels among junior and intermediate trainees, but not in senior trainees in whom an equally sized network of channels remained activated. (Figure 2).

DISCUSSION

Senior trainees are better able to cope with intra-operative cognitive demands and stabilise their performance under pressure, perhaps due to enhanced PFC recruitment and task engagement. Future work will seek to develop cognitive training strategies that will maintain task engagement among more junior trainees, allowing them to improve performance under pressure.

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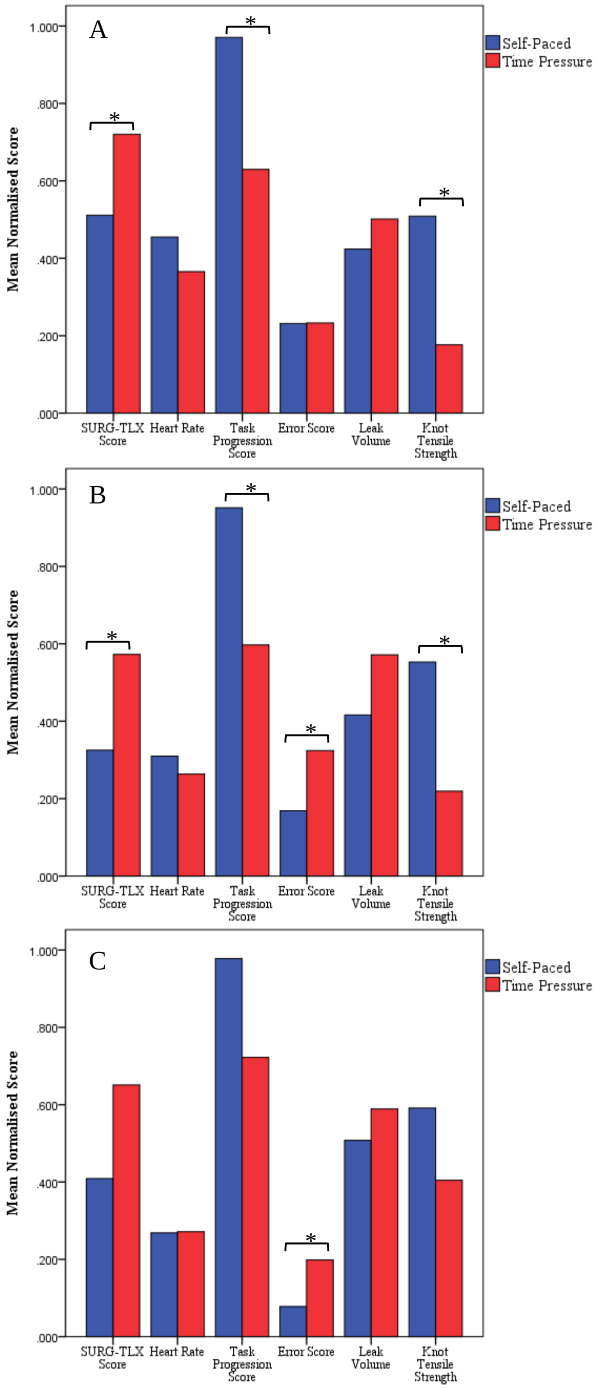

Figure 1. Normalised subjective workload and performance scores in self-paced (blue bars) and time pressure (red bars) conditions in junior trainees (A), intermediate trainees (B) and senior trainees (C). SURG-TLX: Surgical Task Load Index. *p<0.05

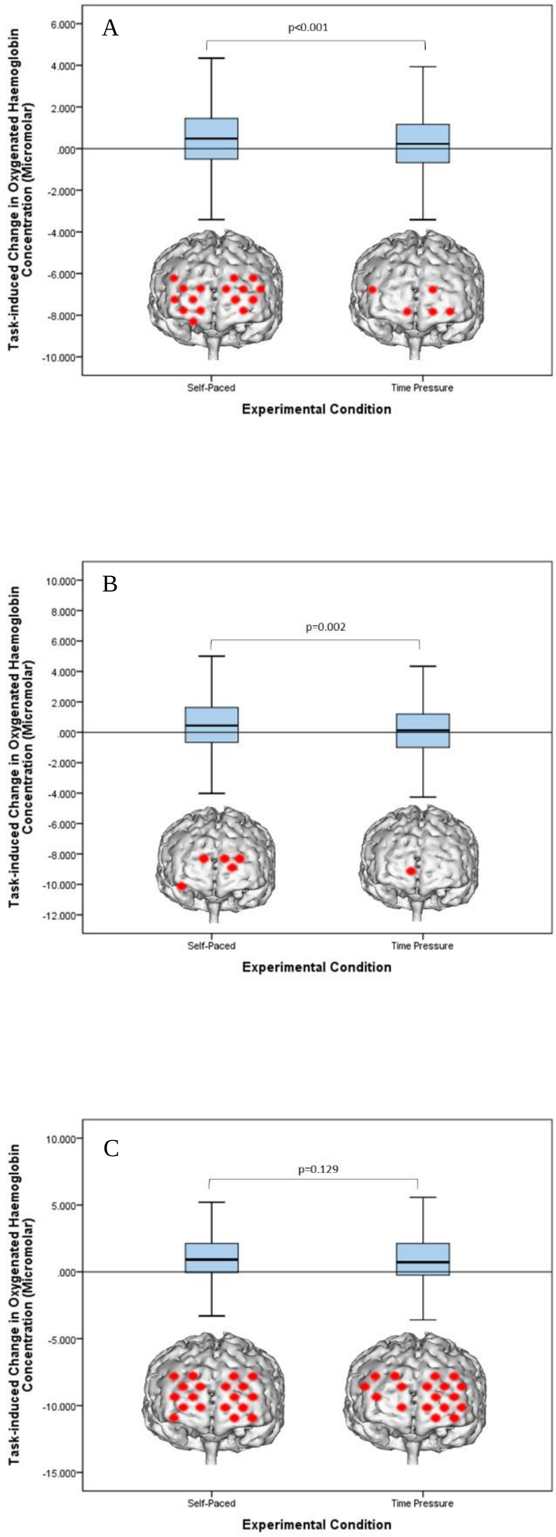

Figure 2. Boxplots demonstrate median task-induced change in oxygenated haemoglobin concentration averaged across channels in each conditions in junior trainees (A), intermediate trainees (B) and senior trainees (C). The 3D MRI reconstructions demonstrate activated channels in each condition based on a statistically significant increase in task-induced HbO_2 concentration.