HIGHER CENTRES MAY ENCODE CARDIORESPIRATORY RESPONSES TO EXERCISE WITHOUT MOVEMENT FEEDBACK IN HUMANS

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INTRODUCTION

How humans can match the cardiorespiratory responses to the increase in metabolic rate of exercise has proved difficult to unravel. We have used Positron Emission Tomography (PET) to identify the neuroanatomical correlates underlying 'central command' during imagination of exercise under hypnosis whilst at rest, in order to uncouple 'central command' from peripheral feedback.

METHODS

Experimentally naive and athletically untrained subjects were familiarised with leg exercise cycle ergometry in the semi-reclined position (Figure 1). On another day subjects were hypnotised on the scanning table, after which the head was positioned to minimise movement under laser beam alignment (Figure 2A-B). The positron emitting $^{15}0$ in the form of 5mCi of $H_2{}^{15}0$ was given iv and breathing and HR were recorded.

Positron emission tomography

Three cognitive conditions were used: I, 'imagination of cycle freewheeling downhill'(no change in heart rate, HR, or ventilation, $\dot{V}_I$): II, 'imagination of exercise' cycling uphill (increased HR by12% and V_I by 30% of the actual exercise response): III, volitionally-driven hyperventilation to match that achieved in II (no change in HR). We employed cognitive subtraction methodology to create two contrasts (A and B) in two separate studies with different subjects (n=4 for both; eight scans per subject). *Contrast A* (II minus I) highlighting cerebral areas involved in the imagination of exercise and *Contrast B* (III minus I) highlighting areas activated in the direct volitional control of breathing. End-tidal PCO_2 was held constant throughout PET scanning. (n=4 for both; eight scans per subject).

Figure 1

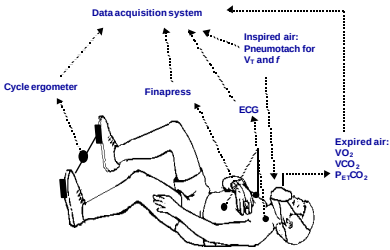
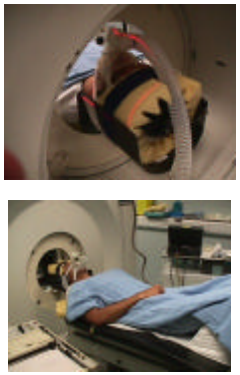


Figure 2



RESULTS

The supplementary motor area (SMA), superolateral sensorimotor areas, the lateral sensorimotor areas and the cerebellum had activations in both Contrasts, whereas the right dorso-lateral prefrontal cortex, premotor area (PMA), left insula cortex, parietal association areas and the thalamus were activated in *Contrast A* alone. The SMA/PMA, cerebellum and the dorso-lateral prefrontal cortex are concerned with volitional/motor control, including that of the respiratory muscles, whereas the left insula cortex is concerned with vagal modulation of HR.

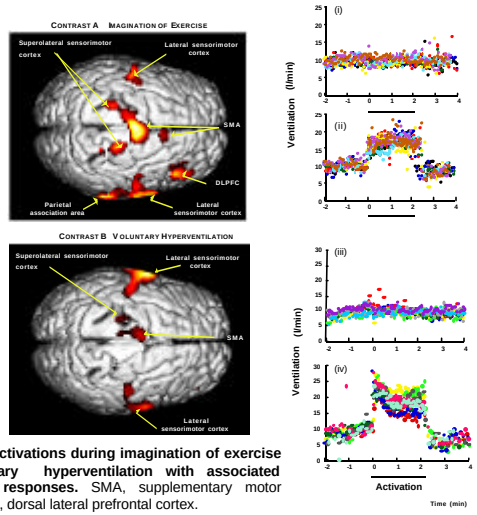


Figure 3. Activations during imagination of exercise and voluntary hyperventilation with associated respiratory responses. SMA, supplementary motor area, DLPFC, dorsal lateral prefrontal cortex.

CONTRAST A (Imagined Exercise)

		LEFT					RIGHT				
		x	y	z	Z	p	x	y	z	Z	p
Dorso -lateral prefrontal area)							43	24	36	4.8	<0.001 *
Supplementary motor area (SMA)							4	-9	64	5	<0.001*
							8	12	62	3.6	<0.001
Premotor area (PMA)							59	3	19	4.4	<0.001
Supero-lateral sensorimotor		-17	-34	56	3.5	<0.001	18	-29	63	4	<0.001
Lateral sensorimotor		-43	-15	39	3.4	<0.001	43	-9	52	3.3	0.001
Insula		-47	-11	17	3.4	0.001					
Parietal lobe											
Precuneus		-10	-36	45	3.4	<0.001					
Medial parietal		-13	-46	26	3.6	<0.001					
Temporo -parietal junction							62	-40	19	4.6	<0.001
Cerebellum											
Antero -lateral		-24	-60	-24	3.5	<0.001	22	-60	-26	4.2	<0.001
Antero -medial		-12	-50	-27	4.2	<0.001					
Postero-lateral		-29	-38	-44	3.2	0.001					
Thalamus							1	-9	15	4.1	<0.001

CONTRAST B (Voluntary hyperventilation)

SMA		-4	-11	54	4.7	<0.001					
Supero-lateral sensorimotor		-4	-25	57	2.6	0.005					
Posterior temp/parietal		-45	-34	-12	4.7	<0.001					
Lateral sensorimotor	(a)	-48	-5	19	7	<0.001*	43	-19	36	3.9	<0.001
	(b)	-56	-15	15	4.8	<0.001*	55	-5	21		
										5.1	<0.001*
Insula							47	-7	21	3.2	0.001
Cerebellum	(a)	-38	-63	-41	3.9	<0.001	11	-69	-48	3.2	0.001
	(b)	-8	-63	-28	3.4	<0.001					

Table 1. Stereotactic coordinates (mm) in Talairach space of voxels maximally activated within sites; voxels are unit cubes of 2 mm side length. significant after correction for multiple comparisons (a) from SPM (b) correlation between voxel activation and V_I, Z>4.8. x, lateral to midline, +ve to right; y, anterior/posterior to anteriorcommisure +ve anterior; z, superior/ inferior to anterior/posterior commisural plane, +ve superior .

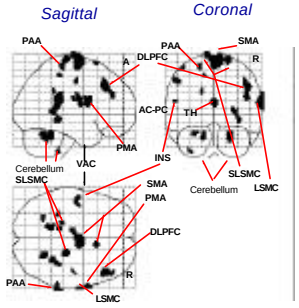


Figure 4. Activations in three views during imagination of exercise at rest. A - Anterior; AC-PC Commissural plane; VAC- vertical plane through anterior commissure; SMA - Supplementary motor area ; PMA - Premotor Area; DLPFC - Dorso-lateral prefrontal cortex; PAA - parietal association area; INS - Insula; TH - Thalamus; SLSMC - Superolateral sensorimotor cortex; LSMC - Lateral sensorimotor cortex.

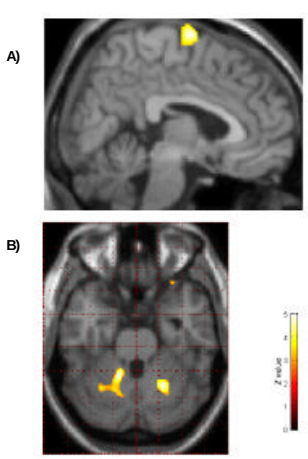


Figure 5. Areas of activation during imagination of exercise (compared to imagination of freewheeling downhill) overlayed on a 'typical' MRI.

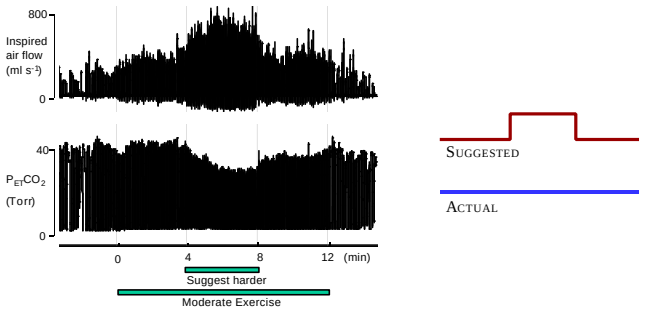


Figure 6. Altered perception of exercise load during actual exercise

CONCLUSIONS

A significant component of the respiratory response to 'exercise', in the absence of both movement feedback and an increase in CO_2 production, can be generated by what appears to be a behavioural response, given the identified neuroanatomical areas activated.

ACKNOWLEDGEMENTS

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