Psychobiology of Physical Activity Behaviour: Theory and Innovative Strategies to Increase Exercise Adherence

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The Problem
Professor Lieberman (2015): “Many lines of evidence indicate that humans evolved to be adapted for regular, moderate amounts of endurance physical activity into late age. However, because energy from food was limited, humans also were selected to avoid unnecessary exertion.”
Adults performing ≥150 min/week of moderate intensity aerobic activity

Based on accelerometry data from the 2008 Health Survey of England
Exercise and gene expression: physiological regulation of the human genome through physical activity

Frank W. Booth *, Manu V. Chakravarthy † and Espen E. Spangenburg  * Journal of Physiology (2002), 543.2, pp. 399–411

Physical inactivity

Failure to maintain homeostatic signaling of gene expression at the Paleolithic level

Nucleus

Genes requiring physical activity are also disease-susceptibility genes

Inhibition of “health”-promoting proteins

Activation of “disease”-promoting proteins

Alteration of intracellular homeostasis, i.e., change of the evolutionarily conserved Paleolithic set points for metabolism

Exceed threshold of physiological significance

Manifestations of pathophysiologic state of overt clinical symptoms (hyperglycemia, hyperinsulinemia, dyspnea, angina, exercise intolerance)

SURVIVAL
Health Consequences of Physical Inactivity
Correlates of physical activity: why are some people physically active and others not?

Adrian E Bauman, Rodrigo S Reis, James F Sallis, Jonathan C Wells, Ruth J F Loos, Brian W Martin, for the Lancet Physical Activity Series Working Group*

Figure 1: Adapted ecological model of the determinants of physical activity
“To properly understand behaviour, we must obtain both ultimate and proximate explanations. Put briefly, **ultimate explanations** are concerned with why a behaviour exists, and **proximate explanations** are concerned with how it works.”
Ultimate Explanations:
Why are humans lazy?
Because it is good to be fat
Body Fat = 3.6%  
Bonobo Female  

Body Fat = 22.0%  
Fit Human Female  

(Gallagher et al., 2000; Zihlman and Bolter, 2015)
Fitness Functions of Body Fat

- Buffering starvation
- Buffering stochasticity
- Adaptation to the cold
- Growth
- Buffering the brain
- Reproduction
- Immune function
- Psychosocial stress
- Sexual selection

(Prospective Studies Collaboration, 2009; West, 2012)
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(Prospective Studies Collaboration, 2009; West, 2012)
Energy Balance

Energy consumed in food and beverages

Energy expended for basal needs, activity, and to process and digest food

Weight gain

Energy balance

Weight loss
Food Landscape Now
Food Landscape Then
Physical activity was essential for food intake but requires energy, e.g. males would spend 1798 kcal in a persistence hunt at optimal running speed (Steudel-Numbers and Wall-Scheffler, 2009)
Physical Labour + Little Food

Five starving men in German concentration camp at time of liberation by U.S. Army
Professor Lieberman (2015): “Many lines of evidence indicate that humans evolved to be adapted for regular, moderate amounts of endurance physical activity into late age. However, because energy from food was limited, humans also were selected to avoid unnecessary exertion.”
People minimize the amount of effort they exert in order to obtain desirable outcomes (Ferrero, 1894; Hull, 1943; Zipf, 1949).

In the economy of action, effort is a cost. Laziness is built deep into our nature (Kaheneman, 1973).
Principle of Least Effort
Principle of Least Effort

Self-reported % of normal-weight women meeting CDC guidelines for moderate intensity LTPA (Ariazza-Jones et al., 1998)
Proximate Explanations
Brain Regulation of Body Fat

(Friedman, 2010)
Components of Daily Energy Expenditure

- **Thermic effect of feeding**: 8%
- **Energy expenditure of physical activity**: 17%
- **Resting energy expenditure**: 75%

**Sedentary Person (1800 kcal/d)**
- Thermic effect of feeding: 8%
- Energy expenditure of physical activity: 17%
- Resting energy expenditure: 75%

**Physically Active Person (2200 kcal/d)**
- Thermic effect of feeding: 8%
- Energy expenditure of physical activity: 32%
- Resting energy expenditure: 60%

Brain regulation of PA behaviour in humans
PHYSICAL ACTIVITY BEHAVIOUR

PSYCHOLOGICAL LEVEL OF EXPLANATION
Psychological Constructs and Theories

BIOLOGICAL LEVEL OF EXPLANATION
Neural Correlates, Neurobiology, Genetics
Psychological Level
Perception of Effort

- It is a conscious sensation of strain and labour, a feeling that intensifies the harder a person tries.

- Unlike the strain felt from some external force (like having one’s arm pulled), effort feels mustered from within.

- Feelings of effort are experienced during:
  - Physical exertion (e.g., lifting weights);
  - Mental concentration (e.g., studying statistics);
  - Self-restraint (e.g., dieting).

- From Preston and Wagner (2009).
Rating of Perceived Exertion (Borg, 1965)

<table>
<thead>
<tr>
<th>Physical Stimulus</th>
<th>Perceptual Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Very, very light</td>
</tr>
<tr>
<td>7</td>
<td>Very light</td>
</tr>
<tr>
<td>8</td>
<td>Fairly light</td>
</tr>
<tr>
<td>9</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>10</td>
<td>Hard</td>
</tr>
<tr>
<td>11</td>
<td>Very hard</td>
</tr>
<tr>
<td>12</td>
<td>Very, very hard</td>
</tr>
</tbody>
</table>
Leg Effort and Respiratory Effort

Figure 3. Intensity of Leg-Muscle Effort and Dyspnea Measured by the Borg Scale during Cycle-Ergometer Exercise in Fit Young Men. The left-hand panel shows leg effort and the degree of dyspnea during incremental exercise; the middle and right-hand panels show leg effort and the degree of dyspnea, respectively, during constant exercise at several levels, expressed as percentages of peak oxygen consumption ($V_O^{\text{max}}$). MPO denotes maximal power output. Adapted from Kearon et al., with the permission of the publisher.

(Jones and Killian, 2000)
Potential motivation is the maximum effort an individual would be willing to exert to satisfy a motive.
Unfit/Fatigued/Placebo  Fit/Non Fatigued/Caffeine

Running at 12 km/h
Determinants of Potential Motivation

- **Reward** value
- **Need** for the reward
- **Contingency** of the reward upon completion of the task (instrumental behaviour)

*(Wright, 2008)*
Hunting

Gathering

In the past, food was main reward of PA
Now main reward of PA for health is to avoid
Public Health Campaigns

Physical activity benefits for adults and older adults

- **Benefits**: Health, Improves Sleep, Maintains Healthy Weight, Manages Stress, Improves Quality of Life

**Type II Diabetes** -40%  
**Cardiovascular Disease** -35%  
**Falls, Depression and Dementia** <30%  
**Joint and Back Pain** -25%  
**Cancers (Colon and Breast)** -20%

**What should you do?**

- For a healthy heart and mind: Be Active
- To keep your muscles, bones and joints strong: Build Strength
- To reduce your chance of falls: Improve Balance

**Sit Less**

**Vigorous Intensity**
- Run
- Sport
- Stairs

**Moderate Intensity**
- Walk
- Cycle
- Swimming
- Housework
- Computer
- Carry Bags
- Bowls

**Minutes per week**

- 75 or 150
- Vigorous intensity
- Moderate intensity
- A combination of both

**Break up sitting time**

- 2 days per week

Something is better than nothing. Start small and build up gradually; just 10 minutes at a time provides benefit. Make a start today: it’s never too late!


TOO BUSY TO EXERCISE?

**You don’t skip tying your shoes because you are too busy.**

DON’T SKIP OUT ON YOUR HEALTH!

PARC
parc.ophea.net
Discounting of Future Events

(Kalenscher and Windergen, 2011)
Most Effective Public Health Campaign Ever

Take the stairs every day

or you will get cancer

Get off two stops earlier or you will die tomorrow!

Walk 30 minutes a day or you will have an heart attack within 24 hours
## Financial Incentives for Exercise Adherence in Adults
### Systematic Review and Meta-Analysis


<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Incentive</th>
<th>Control</th>
<th>Mean difference IV, Fixed, 95% CI Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epstein (1980)</td>
<td>76.5</td>
<td>57.5</td>
<td>19.00 (-4.71, 42.71) 1980</td>
</tr>
<tr>
<td>Epstein (1980)</td>
<td>79.0</td>
<td>57.5</td>
<td>21.50 (-4.66, 47.66) 1980</td>
</tr>
<tr>
<td>Wing (1996)</td>
<td>60.7</td>
<td>52.2</td>
<td>8.50 (-11.05, 28.05) 1996</td>
</tr>
<tr>
<td>Courneya (1997)</td>
<td>45.42</td>
<td>31.42</td>
<td>14.00 (4.04, 23.96) 1997</td>
</tr>
<tr>
<td>Jeffery (1998)</td>
<td>44.4</td>
<td>34.67</td>
<td>9.73 (-2.49, 21.95) 1998</td>
</tr>
<tr>
<td>Charness (2009)</td>
<td>108.89</td>
<td>33.33</td>
<td>75.56 (59.81, 91.31) 2009</td>
</tr>
<tr>
<td>Charness (2009)</td>
<td>145.00</td>
<td>18.75</td>
<td>126.25 (113.39, 139.11) 2009</td>
</tr>
</tbody>
</table>

**Total (95% CI)**

- Mean: 195
- SD: 199
- Weight (%): 100.0%
- Mean difference IV, Fixed, 95% CI: 11.55 (5.61, 17.50)

**Heterogeneity:** Chi² = 2.05, df = 5 (p = 0.84); I² = 0%

**Test for overall effect:** z = 3.81 (p = 0.0001)

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**Figure 2.** Exercise session attendance (%) 4–26 weeks) comparing use of incentives versus no incentives

*Note: The Charness 2009 paper reported on two studies, so results are given for each.*
Barriers to Exercise

- Factor analysis of responses from 650 adults gave four main barriers:
  - **Physical Exertion** (e.g., exercise is hard work for me)
  - **Exercise Milieu** (e.g., places for me to exercise are too far away)
  - **Time Expenditure** (e.g., exercise takes too much of my time)
  - **Family Discouragement** (e.g., my spouse does not encourage exercising)

(Sechrist et al., 1987)
# Perceived Exercise Benefits and Barriers of Non-Exercising Female University Students in the United Kingdom

<table>
<thead>
<tr>
<th>Perceived Barriers Items</th>
<th>M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exercise Milieu Sub-scale</strong></td>
<td></td>
</tr>
<tr>
<td>9: Places for me to exercise are too far away</td>
<td>2.69 (0.70)</td>
</tr>
<tr>
<td>12: I am too embarrassed to exercise</td>
<td>1.85 (0.83)</td>
</tr>
<tr>
<td>14: It costs too much money to exercise</td>
<td>2.26 (0.86)</td>
</tr>
<tr>
<td>16: Exercise facilities do not have convenient schedules for me</td>
<td>2.09 (0.74)</td>
</tr>
<tr>
<td>28: I think people in exercise clothes look funny</td>
<td>2.04 (0.88)</td>
</tr>
<tr>
<td>42: There are too few places for me to exercise</td>
<td>2.10 (0.77)</td>
</tr>
<tr>
<td><strong>Time Expenditure Sub-scale</strong></td>
<td></td>
</tr>
<tr>
<td>4: Exercising takes too much of my time</td>
<td>2.31 (0.81)</td>
</tr>
<tr>
<td>24: Exercise takes too much time from family relationships</td>
<td>1.95 (0.67)</td>
</tr>
<tr>
<td>37: Exercise takes too much time from my family responsibilities</td>
<td>2.04 (0.71)</td>
</tr>
<tr>
<td><strong>Physical Exertion Sub-scale</strong></td>
<td></td>
</tr>
<tr>
<td>6: Exercise tires me</td>
<td>2.69 (0.70)</td>
</tr>
<tr>
<td>19: I am fatigued by exercise</td>
<td>2.57 (0.75)</td>
</tr>
<tr>
<td>40: Exercise is hard work for me</td>
<td>2.63 (0.70)</td>
</tr>
<tr>
<td><strong>Family Discouragement Sub-scale</strong></td>
<td></td>
</tr>
<tr>
<td>21: My spouse (or significant other) does not encourage exercising</td>
<td>2.15 (0.87)</td>
</tr>
<tr>
<td>33: My family members do not encourage me to exercise</td>
<td>1.96 (0.65)</td>
</tr>
<tr>
<td><strong>All Barriers items of all subscales</strong></td>
<td>2.22 (0.46)</td>
</tr>
</tbody>
</table>

(Lovell et al., 2010)
Exercise Intensity and Duration

RPE (6-20) vs Time (min) for different power outputs:
- 340 W
- 310 W
- 280 W
Exercise Intensity and Adherence

(Perri et al., 2002)
Exercise Duration and Adherence

Mental Fatigue
Personal and Environmental Factors Associated With Physical Inactivity Among Different Racial–Ethnic Groups of U.S. Middle-Aged and Older-Aged Women

Table 3
Most Frequently Reported Perceived Barriers, Along With Relative Rankings, for the Sample as a Whole (N = 2,912) and for Each Racial–Ethnic Subgroup

<table>
<thead>
<tr>
<th>Perceived barrier</th>
<th>% total sample</th>
<th>Overall rank</th>
<th>% White (rank)</th>
<th>% Black (rank)</th>
<th>% American Indian–Alaskan Native (rank)</th>
<th>% Hispanic (rank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of time</td>
<td>22.3</td>
<td>1 (tie)</td>
<td>24.6 (1)</td>
<td>17.0 (5)</td>
<td>24.8 (2)</td>
<td>22.5 (3)</td>
</tr>
<tr>
<td>Caregiving duties</td>
<td>22.3</td>
<td>1 (tie)</td>
<td>20.7 (2)</td>
<td>20.2 (3)</td>
<td>23.6 (4)</td>
<td>25.6 (1)</td>
</tr>
<tr>
<td>Lack energy</td>
<td>21.7</td>
<td>3</td>
<td>19.9 (4)</td>
<td>21.1 (2)</td>
<td>25.1 (1)</td>
<td>20.3 (4)</td>
</tr>
<tr>
<td>Too tired</td>
<td>20.7</td>
<td>4</td>
<td>20.4 (3)</td>
<td>19.0 (4)</td>
<td>24.5 (3)</td>
<td>18.9 (5)</td>
</tr>
<tr>
<td>Lack safe place to exercise</td>
<td>20.1</td>
<td>5</td>
<td>16.5 (6)</td>
<td>22.9 (1)</td>
<td>23.0 (5)</td>
<td>17.6 (6)</td>
</tr>
<tr>
<td>Self-conscious about physical appearance</td>
<td>19.6</td>
<td>6</td>
<td>18.9 (5)</td>
<td>15.1 (7)</td>
<td>20.6 (6)</td>
<td>23.8 (2)</td>
</tr>
<tr>
<td>Not in good health</td>
<td>16.2</td>
<td>7</td>
<td>13.6 (7)</td>
<td>16.8 (6)</td>
<td>19.2 (8)</td>
<td>15.2 (8)</td>
</tr>
<tr>
<td>Afraid of injury</td>
<td>15.3</td>
<td>8</td>
<td>11.0 (9)</td>
<td>14.9 (8)</td>
<td>19.4 (7)</td>
<td>16.3 (7)</td>
</tr>
<tr>
<td>Bad weather</td>
<td>10.4</td>
<td>9</td>
<td>12.4 (8)</td>
<td>8.8 (9)</td>
<td>11.2 (9)</td>
<td>8.8 (9)</td>
</tr>
<tr>
<td>Others discourage me</td>
<td>5.6</td>
<td>10</td>
<td>3.4 (10)</td>
<td>6.2 (10)</td>
<td>7.1 (10)</td>
<td>5.3 (10)</td>
</tr>
</tbody>
</table>

(King et al., 2000)
Table 5
Simultaneous Logistic Regression: Correlates of Being Sedentary Versus Underactive–Active (n = 2,633)

<table>
<thead>
<tr>
<th>Correlate</th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personal barriers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others discourage me from exercising</td>
<td>1.07</td>
<td>0.98–1.17</td>
</tr>
<tr>
<td>Self-conscious about physical appearance</td>
<td>1.08*</td>
<td>1.01–1.14</td>
</tr>
<tr>
<td>Afraid of injury</td>
<td>1.05</td>
<td>0.98–1.13</td>
</tr>
<tr>
<td>Lack of time</td>
<td>0.95</td>
<td>0.89–1.02</td>
</tr>
<tr>
<td><strong>Too tired</strong></td>
<td>0.92**</td>
<td>0.85–0.99</td>
</tr>
<tr>
<td>Lack safe place to exercise</td>
<td>0.98</td>
<td>0.93–1.05</td>
</tr>
<tr>
<td>Caregiving duties</td>
<td>0.95</td>
<td>0.90–1.01</td>
</tr>
<tr>
<td>Bad weather</td>
<td>1.00</td>
<td>0.93–1.08</td>
</tr>
<tr>
<td>Not in good health</td>
<td>0.93*</td>
<td>0.86–0.99</td>
</tr>
<tr>
<td><strong>Lack energy</strong></td>
<td>0.90**</td>
<td>0.84–0.97</td>
</tr>
</tbody>
</table>

*Note. CI = confidence interval.

* p < .05.  ** p < .01.  *** p < .001.

(King et al., 2000)
Mental Fatigue and Perception of Effort

Mentally Fatiguing Task

Endurance Performance Test

AX-Continuous Performance Task (AX-CPT) for 90 min

Time to Exhaustion at 230W (80% of Peak Power Output)

Randomized crossover experiment N = 16

(Marcora et al., JAP 2009)
Mental Fatigue and Perception of Effort

Mentally Fatiguing Task

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AX-Continuous Performance Task (AX-CPT) for 90 min

Time to Exhaustion at 230W (80% of Peak Power Output)

Randomized crossover experiment N = 16

(Marcra et al., JAP 2009)
Mental Fatigue and Perception of Effort

# significant difference at exhaustion; † significant main effect of treatment at isotime

(Marcora et al., JAP 2009)
Mental Fatigue and Perception of Effort

(Marcora et al. JAP 2009)
Biological Level
Neurophysiology of Perception of Effort

A  Afferent feedback model of perceived exertion

Central command (pre-motor and/or motor areas) → Skeletal muscles

Sense of effort (somatosensory areas)

B  Corollary discharge model of perceived exertion

Central command (pre-motor and/or motor areas) → Skeletal muscles

Sense of effort (somatosensory areas)

(Marcora. JAP 2009)
Afferent Feedback Model of Perceived Effort

Fig. 1. Teleoanticipation and perceived exertion. A precise regulation of exercise performance may be achieved through a process of teleoanticipation. The perception of exertion results from the interpretation of afferent sensations against an expected outcome.

(Hampson et al., 2001)
Cardiopulmonary Sources of Afferent Feedback

RPE and heart rate during incremental exercise tests in 2,560 Men and Women

(Scherr et al., 2013)
Cardiopulmonary Sources of Afferent Feedback

Heart Rate (beats/min)

Perceived Exertion (RPE)

Nine men with chronic atrial fibrillation during treadmill exercise testing

(Myers et al., 1987)
Peripheral/Metabolic Sources of Afferent Feedback

RPE and blood lactate during incremental exercise tests in 2,560 Men and Women

(Scherr et al., 2013)
Peripheral/Metabolic Sources of Afferent Feedback

Experimental Muscle Pain

(Khan et al., 2011)
Peripheral/Metabolic Sources of Afferent Feedback

Isometric Contractions of Elbow Flexors

Figure B. Subjects instructed to “pull up with 5%, 10%, 25%, 50%, or 75% of your maximal effort” (RPE Production Method)

(Khan et al., 2011)
Afferent Feedback and Perception of Effort

Spinal / Epidural Anaesthetic

- Patient can be responsive and awake
- All the areas below the site of the epidural will be anaesthetised

Epidural anaesthesia at lumbar level

Cycling exercise for 20 min at 46% VO2max

(Kjaer et al. 1999)
Afferent Feedback and Perception of Effort

**Rating of Perceived Exertion (RPE)**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Epidural</th>
<th>Control</th>
<th>Epidural</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normoxia</strong> (20.9% oxygen)</td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hypoxia</strong> (11.5% oxygen)</td>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Kjaer et al. 1999)
Peripheral/Metabolic Sources of Afferent Feedback

5 min of isometric one leg extension at same absolute force (10% of initial MVC = 21 ± 2 Nm)

2 min of isometric one leg extension at same relative force (30% of current MVC)

Mitchell et al. (1989)
Corollary Discharge Model of Perceived Effort

(de Morree and Marcora, 2015)
Motor-Related Cortical Potentials

Electroencephalography (EEG)
Central Command and Perception of Effort

Left. Experimental set-up. Right. Strength loss after fatiguing protocol. † significant paired difference.

De Morree et al. Psychophysiology 2012; 49(9): 1242-1253
Central Command and Perception of Effort

Rating of perceived effort for all four weightlifting conditions. Data are presented as means ± standard deviations. # Significant main effect of fatigue ($p < 0.001$), * significant main effect of weight ($p < 0.001$).
Central Command and Perception of Effort

Movement-related cortical potentials at five electrodes for the four weightlifting conditions over time. 

contra is contralateral to the movement and ipsi is ipsilateral to the movement. Time 0 s is EMG onset.
Within-subject correlation between rating of perceived effort and average Cz amplitude during the first 1000 ms of movement. Each data point represents the means ± standard errors for one of the four conditions. The correlation coefficient was $r_{(14)} = -0.64$ ($p < 0.001$).
Disrupting the Supplementary Motor Area Makes Physical Effort Appear Less Effortful

Figure 2. Localization of the cTBS sites in the 12 participants for the SMA (green), M1 (red), and control (blue) conditions. These coordinates were obtained by projecting the stimulation sites onto the individual brain MRI of each participant, which was then normalized into the Talairach space.

Disrupting the Supplementary Motor Area Makes Physical Effort Appear Less Effortful

Figure 3. Continuous measurements of effort perception. Each column corresponds to a different effort perception variable. Error bars indicate the SEM. Top row, Relationship between each variable and the effort intensity condition. Bottom row, Changes observed in the four continuous variables after cTBS application to each of the three cTBS sites. Main effects of cTBS sites are illustrated for all variables except the force prediction in trial t+1, in which the EFFORT INTENSITY × cTBS SITE interaction is shown instead, because this was the only significant result obtained from the statistical analysis.
Anterior Cingulate Cortex (ACC)

Rating of Perceived Exertion (RPE) during perceived uphill and downhill cycling at a constant workload

Anterior Cingulate Cortex (ACC)

Coregistered single-positron-emission computed tomography and magnetic resonance imaging data during perceived uphill and downhill cycling at a constant workload

Separate neural pathways process different decision costs

Peter H Rudebeck, Mark E Walton, Angharad N Smyth, David M Bannerman & Matthew F S Rushworth

Anterior cingulate cortex (ACC) lesions affect how much effort rats decided to invest for rewards ("lazy rats").
Novel Interventions to Facilitate Physical Activity Behaviour
Investments that Work for Physical Activity

- ‘Whole-of-school’ programs
- **Transport policies and systems** that prioritise walking, cycling and public transport
- **Urban design regulations and infrastructure** that provides for equitable and safe access for recreational physical activity, and recreational and transport-related walking and cycling across the life course
- Physical activity and NCD prevention integrated into **primary health care systems**
- **Public education**, including mass media to raise awareness and change social norms on physical activity
- **Community-wide programs** involving multiple settings and sectors and that mobilize and integrate community engagement and resources
- **Sports systems and programs** that promote ‘sport for all’ and encourage participation across the life span

(Toronto Charter for Physical Activity, 2010)
BCTs in intervention studies to increase self-efficacy and PA in people with obesity

- Goal setting (behaviour)
- Prompt self-monitoring of behaviour
- Prompt practice
- Barrier identification/Problem solving
- Relapse prevention/coping planning
- Provide instruction on how to perform the behaviour
- Plan social support/social change
- Provide information on consequences of behaviour in general
- Provide information on consequences of behaviour for the individual
- Set graded tasks
- Prompt review of behavioural goals
- [...]
Can Doping be a Good Thing? Using Psychoactive Drugs to Facilitate Physical Activity Behaviour

(Marcora, 2016)
Pharmacotherapy as a BCT for other health behaviours
Cheap, widely available, safe and effective psychoactive drug
Neuronal adenosine release, and not astrocytic ATP release, mediates feedback inhibition of excitatory activity

PNAS | April 17, 2012 | vol. 109 | no. 16 | 6265–6270

Ditte Lovatt\textsuperscript{a,1,2}, Qiwu Xu\textsuperscript{a,1}, Wei Liu\textsuperscript{a,3}, Takahiro Takano\textsuperscript{a}, Nathan A. Smith\textsuperscript{a}, Jurgen Schnerrmann\textsuperscript{b}, Kim Tieu\textsuperscript{a}, and Maiken Nedergaard\textsuperscript{a,2}
Central Command and RPE


De Morree et al. Journal of Applied Physiology 2014 : 1514-1523
Movement-related cortical potentials at five electrodes for the first 50 and last 50 contractions in the caffeine and placebo conditions. Time 0 ms is EMG onset.
Review

Effects of caffeine ingestion on rating of perceived exertion during and after exercise: a meta-analysis

M. Doherty, P. M. Smith
Effects of Caffeine in Inactive People

Aims
Investigate whether the effect of caffeine ingestion on psychological responses to HIIT are associated with changes in exercise behaviour, as determined by choice.

Study Design
Double-blind, repeated measures crossover design

Participants
Eight physically inactive adults (M±SD) age, 34±12 years; height 168±7 cm; weight 85±23 kg; BMI 31±7; and VO2max 32±6.

Thanks to Joel Chidley and Dr Gurprit Lall
Study Protocol and Treatment

Inclined treadmill walking - HIIT

Familiarisation

Caffeine (3mg/kg) Or placebo

\(\sim 90\% \dot{VO}_2^{\text{max}}\)

\(\sim 60\% \dot{VO}_2^{\text{max}}\)

Time (mins):

5 4 3 4 3 4 3 4 3

Total 33mins

Outcome Measures

Measurements during exercise:
Heart rate (HR)
Rating of perceived exertion (RPE, Borg 6-20)
Feeling Scale (FS)
Exercise-induced muscle pain (pain, Cook 0-10)

Measurements pre and/or post exercise:
• Physical Activity Enjoyment Scale (PACES)
• Brunel Mood Scale (BRUMS)
• Exercise ‘liking’
• 10-minutes post exercise, session RPE

Choice measure:
On three occasions, subjects were asked to choose whether they preferred ‘this’ or the previous session – providing 3 opportunities to choose between treatment pairs.
**Results**

*Indicates a significant main effect of condition *p* ≤ 0.1; ** *p* ≤ 0.05; *** *p* ≤ 0.01.

† Indicates a significant main effect of time *p* ≤ 0.1; †† *p* ≤ 0.05; ††† *p* ≤ 0.01
Results

*Indicates a significant main effect of condition \( p \leq 0.1 \); **\( p \leq 0.05 \); ***\( p \leq 0.01 \).

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Results

*Indicates a significant main effect of condition \( p \leq 0.05; \) **\( p \leq 0.01; \) ***\( p \leq 0.001.\)

† Indicates a significant main effect of time \( p \leq 0.05; \) ††\( p \leq 0.01; \) †††\( p \leq 0.001.\)
Results

A. Session RPE

B. PACES

C. Exercise 'liking'

D. Choice

***

*

Placebo 20%

Caffeine 80%
Future Research

Adherence rate, %

Group, $P < 0.0001$
Group x time, $P < 0.001$

Months of training

BMI

Q1
Q2
Q3
Q4

Questions?