Course Description
The only way in which we can interact with world is through movement. Arguably, humans are equipped with the most advanced motor system compared to other species. We possess a remarkable ability to learn new motor skills and retain memories for those skills throughout life, such as riding a bicycle. The ease with which we perform these skills belies their overwhelming computational complexity, which makes us overlook how important motor skills play in our everyday lives. In this course, we will examine how the nervous system controls movements, how the brain handles enormous computational complexities of movement, how motor skills are learned and consolidated, and how the motor system influences cognition.

https://blackboard.princeton.edu/pucourse/PSY412-NEU412_S2013

Prerequisites
PSY 255 (Cognitive Psychology)

Evaluation:
50% Exams (25% 1st exam on March 13 and 25% 2nd exam on May 1)
25% Precept questions
25% Research proposal

Precepts:
The precept will involve the presentation of two articles by two students each week. You will be assigned to present one paper throughout the semester. The goal of this presentation is not simply go over what the authors wrote in the manuscript, but rather to think deeply about why and how the experiment was conducted. If you are not presenting, then you still have to read the precept papers. In addition, you will need to prepare answers to following questions about each paper and bring these questions with you to class. You will turn these questions in during the precept. These questions can also be used as a model for your presentation during the semester.

1. What was the purpose of the research? What open question did it address?
2. Could the authors have addressed the problem in a different way? Is this the best approach?
3. How do the results support the author’s interpretation? Is it appropriate?
4. What is one problem with the paper or what don’t you understand about the paper?
5. If you were one of the author’s, what would be your next follow-up experiment?
6. If you were a reviewer, would you recommend the article for publication?

Research proposal:
The most fun part of research is thinking up new experiments to answer some burning question. In this research paper, you will come up with a novel hypothesis or question, and design an experiment to test it. The paper will follow a grant format, with these sections: specific aims (1 page), background and significance (1-2 pages), and experimental plan (3-5 pages). I will give you an example grant so that you can get a sense of how your research paper should be formatted. This research paper will be due by the Dean’s Date on May 14.

Weekly Schedule:

**Week 1**
**An introduction to motor behavior**
(M) Why is motor control important?
(W) Why does it seem so easy yet it is so complicated?
   Degrees of freedom, sensorimotor integration, automaticity,

**Week 2**
**Physiology of the motor system**
(M) How do we move a muscle?
   Motor pathways, muscles, spinal cord
(W) How do we coordinate movement of many muscles?
   Motor cortex, cerebellum, and basal ganglia
(F) Precept

Lecture Reading:
Rosenbaum, Motor Control, Chapter 3

Precepts Reading:
Selen, Shadlen, and Wolpert, “Deliberation in the motor system: reflex gains track evolving evidence leading to a decision.” J Neurosci 2012

**Week 3**
**Feedback and feedforward motor control**
(M) What is the role of sensory feedback?
   Visual and proprioceptive feedback, closed-loop control, reflexes
(W) How does the motor system cope with feedback delays?
   Pattern generators, motor programs, motor planning
(F) Precept
**Lecture Reading:**
Schmidt, Motor Control and Learning, Chapter 5

**Precepts Reading:**

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**Week 4**

**The motor control system I**

Feb 25

(M) What is specified in a motor command?
*Endpoint control, trajectory control, hierarchical control, direction vs. force, eye-hand calibration, bimanual movements (UC task)*

(W) What are the computational problems of motor control?
*Equilibrium point, internal models*

(F) Precept

**Lecture Reading:**

**Precept Reading:**
Izawa, Criscimagna, Shadmehr, “Cerebellar contributions to reach adaptation and learning sensory consequences of action.” J Neurosci 2012

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**Week 5**

**The motor control system II**

Mar 4

(M) Can you be fast and accurate?
*Fitt’s law, Speed accuracy trade-offs*

(W) What defines movement constraints?
*Optimal feedback control*

(F) Precept

**Lecture reading:**

**Precept Reading:**
Cos, Medleg, Cisek, “The modulatory influence of endpoint controllability on decisions between actions.” J Neurophysiol 2012
Kistemaker, Wong, and Gribble, “The central nervous system does not minimize energy cost in arm movements.” J Neurophysiol 2010
Week 6  Motor skills & Exam  Mar 11
(M) Review
(W) Mid-term Exam
(F) No Percept

Week 7  Motor Skills and Feedback  Mar 25
(M) What defines a skill? How much should you practice?
  Law of practice, blocked vs. mass practice, Closed vs. open skills,
  stages of skill acquisition
(W) What is the role of task feedback?
  Knowledge of results, augmented feedback, reinforcement,
  operant conditioning
(F) Precept

Lecture Reading:
Schmidt, Motor Control and Learning, Chapter 11

Precept Reading:
Lefebvre et al, “Brain activations underlying different patterns of
  performance improvement during early motor skill learning.”
  Neuroimage 2012
Shmuelof, Krakauer, and Mazzoni, “How is a motor skill learned? Change
  and invariance at the levels of task success and trajectory control.”
  J Neurophysiol 2012
Huang et al, “Rethinking motor learning and savings in adaptation
  paradigms: model-free memory for successful actions combines
  with internal models.” Neuron 2011

Week 8  Motor learning and memory I  Apr 1
(M) How do you remember?
  Retention, retrograde interference, anterior grade interference,
  sleep
(W) What are the signs of learning?
  Generalization, transfer
(F) Precept

Lecture Reading:
Schmidt, Motor Control and Learning, Chapter 14

Precept Reading:
Torres-Oviedo and Bastian, “Natural error patterns enable transfer of
  motor learning to novel contexts.” J Neurophysiol 2012
Balitsky Thompson and Henriques, “Visuomotor adaptation and
  intermanual transfer under different viewing conditions.” Exp Brain
  Res 2010
Week 9  
**Motor learning and memory II** 
(M) What is learned on a single movement?  
*Incremental learning*  
(W) What are you learning?  
*Bayes, Structural learning*  
(F) Precept

**Lecture Reading:**  

**Precept Reading:**  
Wei, Wert, and Kording, “*The nervous system uses nonspecific motor learning in response to random perturbations of varying nature.*” J Neurophysiol 2010  
Brayanov and Smith, “*Bayesian and ‘anti-Bayeisan” biases in sensory integration for action and perception in the size-weight illusion.*” J Neurophysiol 2010

Week 10  
**Memory representations**  
(M) Can you tell me what you learned?  
*Explicit and implicit memory systems, serial reaction time task,*  
(W) Do memories compete?  
*Sleep consolidation, interference*  
(F) Precept

**Lecture Reading:**  
Robertson, “*New insights in human memory interference and consolidation.*” Curr Biol 2012

**Precept Reading:**  
Cohen and Robertson, “*Preventing interference between difference memory tasks.*” Nat Neurosci 2011  
Keisler and Shadmehr, “*A shared resource between declarative memory and motor memory.*” J Neurosci 2010

Week 11  
**Integrative approaches**  
(M) Can you chew gum and walk?  
*Dual-task interference, cognitive control, attentional focus*  
(W) What can be gained by examining complex skills?  
*Sports, Embodied cognition*  
(F) Precept

**Lecture Reading:**  
Schmidt, Motor Control and Learning, Chapter 4
Precept Reading:
Malone and Bastian, “Thinking about walking: effects of conscious correction versus distraction on locomotor adaptation.” J Neurophysiol 2010

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<thead>
<tr>
<th>Week 12</th>
<th>Second Midterm</th>
<th>Apr 29</th>
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<tbody>
<tr>
<td>(M) Review</td>
<td>(W) In-class Midterm Exam</td>
<td>(F) No Precept</td>
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Research proposal due on May 14