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SANTA BARBARA • SANTA CRUZ

PSYCHOLOGY DEPARTMENT
UNIVERSITY OF CALIFORNIA, BERKELEY
3210 TOLMAN HALL #1650
BERKELEY, CALIFORNIA 94720-3190

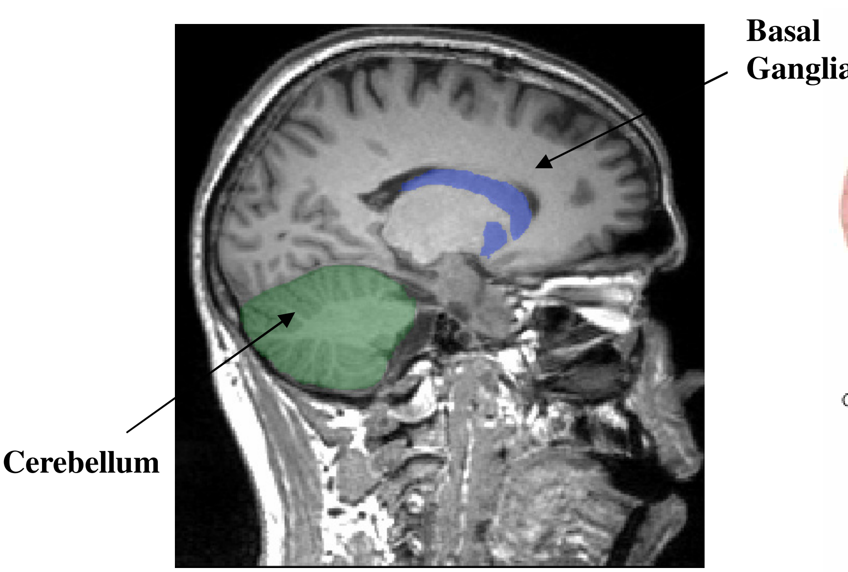
PHONE: (510) 642-5292
FAX: (510) 642-5293

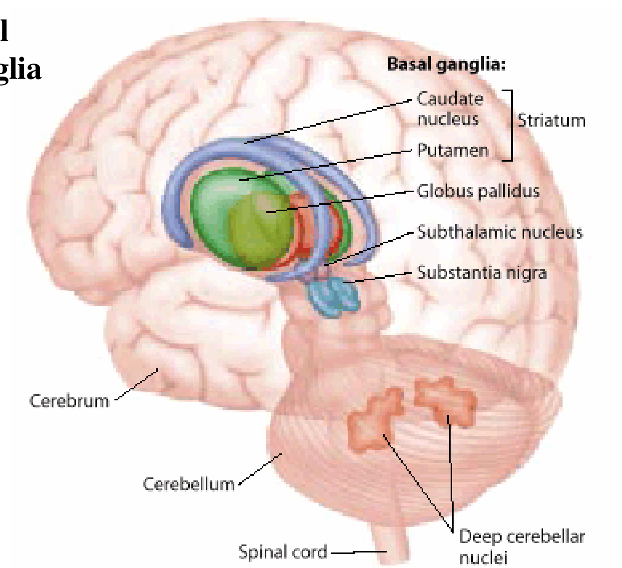
Cognition and Action (CognAc) Lab 2008 Newsletter

September 3, 2008

Summer ends early around Berkeley-- the undergraduates returned this past week and first lectures are already under their belts. The "open" months flew by and although we had an opportunity to visit with many of you as part of our newest projects, some plans went unfilled including the distribution of our annual newsletter. So before the semester reaches a full roar, I wanted to fill you in on some of the recent work in the Cognition and Action lab at UC Berkeley. As always, I begin with a general overview to remind you of our general mission-- this will be a review for many of you so feel free to skip ahead to the report of our newer activities.

The research in the lab focuses on how different types of neurological conditions disrupt skilled movement. Our primary studies explore the functions of what neuroscientists call the "subcortex", the part of the brain that lies under the cerebral cortex, or cerebrum (see the picture). The subcortex is sometimes considered the "ancient" brain, reflecting the fact that the structures that form the subcortex are found in almost all animals, including prehistoric fish, reptiles, birds, as well as mammals. While these animals didn't need to perform complex mental tasks such as balancing checkbooks and driving cars, they did require the neural machinery that allows them to move about and interact with their environment. Animals that can't control their movements are at a huge disadvantage in the natural world. They can't flee from enemies nor can they venture out in search of food and mates. So, it is logical that the systems that control movements are deeply embedded in the brain and that there are numerous similarities in how movements are controlled across a range of different animals.





We have focused on two large structures within the subcortex, the basal ganglia and the cerebellum. If either structure is damaged, the person is likely to have coordination problems. The basal ganglia are the part of the brain that is primarily affected in Parkinson's disease. Many cells in the basal ganglia are dependent on dopamine, one of the chemicals in the brain that allows nerve cells to communicate with each other. Parkinson's disease is caused by a dramatic reduction in the production of dopamine. Cerebellar problems do not result from a loss of a particular brain chemical. Rather, various degenerative disorders, some of which have a known genetic basis, target the cerebellum, resulting in ataxia, or a loss of the fine control of skilled movements. In addition, strokes can affect any part of the brain including the basal ganglia and cerebellum.

Those of you who have participated in our studies for many years know that we are working on several different projects, which might, at times, seem completely unrelated. Nonetheless, there are a number of central themes that guide our work. Most prominent is our goal to understand how the brain produces skilled movements. Note that I talk about how the “brain” produces these actions. Obviously the muscles are also important; you wouldn’t be able to walk or talk or type on a computer if the neural signals were unable to activate the muscles. But, to the surprise of many, much of what determines whether a movement is clumsy or skilled has more to do with the brain than the body. Coordinated actions require that we select the appropriate action once we’ve recognized the environmental conditions. The expert tennis player can’t simply stand fixed on the center of the court and swat the ball as hard as he can. Rather, much of the expertise involves anticipating where the opponent’s shot will land, glancing up to see which part of the court is open, and adjusting the stroke to give the ball just the right spin, speed, and direction. The same holds for basketball; the professionals can all make shots from just about any place on the court when unguarded in practice. The real challenge is in making that shot when there are nine other rather large bodies scattered about the court. In any sport, or in fact, our everyday activities, skilled action requires accurate perception and memory. Thus, our lab doesn’t study motor control in isolation, looking at how people activate and control their muscles. Rather, as the name Cognition and Action implies, we study action from a broad perspective, trying to see how skill builds on so many aspects of our mental abilities.

Let me now turn to a brief update of some of the most recent results to emerge from our studies.

1. Brain imaging studies of movement.

Much of our work involves testing individuals with neurological disorders, asking how the ability to produce skilled movement is disrupted by different disorders. In this way, we not only come to understand the disease processes, but are also able to make inferences about how different parts of the brain contribute to skilled action. Another technique to investigate these questions is to observe brain function while people produce different types of movements. Magnetic resonance imaging (MRI) has become an important tool in the neurosciences over the past decade. We are fortunate to have an MRI center on our campus that is solely devoted to research (there is no medical school or hospital at Berkeley). Many of you are familiar with this procedure. MRI machines can provide exquisite pictures of the human brain. In contrast to standard MRI where the goal is to see the structure, or anatomy of the brain, functional imaging, or fMRI, measures brain activity by observing how oxygen is consumed by different parts of the brain-- nerve cells that are working hard require extra oxygen.

We have used this technique to ask how people produce movements of varying difficulty with either the left or right hand. Consistent with one of the most fundamental observations in neurology, activity is always greater in the side of the brain opposite to the moving hand: thus, when using the right hand, the left side of the brain is more active than the right side of the brain. However, this organization changes when the movements become more complex such as when people produce a sequence of finger movements or have to coordinate the movements of multiple fingers at the same time. Under these conditions, activation is much stronger on the left side of the brain (hemisphere) regardless of whether you are using your right or left hand. Interestingly, this pattern is true for both right- and left-handers. These observations indicate that there is something special about the left hemisphere in the control of complex, or skilled movements. Neurologists have long known that the left hemisphere is more important than the right for language. The same seems to be true for skilled actions. An open question is whether the left hemisphere role in language and skilled action is due to the evolution of a specialized function in the left hemisphere that is shared by language and action, perhaps something about the ability to link together a sequence of gestures. Such sequences are essential for producing sentences. Similarly, sequencing is essential for all of our skilled actions such as knitting a sweater, throwing a ball, or using a knife and fork to eat dinner.

The basal ganglia and the cerebellum are also very active when people produce any type of movement and the level of this activity increases as the movements become more complex. Interestingly, some work from other research centers suggests that each of these brain regions might help compensate when either region is damaged. Thus, there is some evidence to suggest that the cerebellum is more active in individuals with Parkinson's disease compared to neurologically healthy individuals (due to the loss of function in the basal ganglia) and, correspondingly, perhaps more activity in the basal ganglia in people with cerebellar degeneration. We have observed that, in healthy individuals, specific parts of the cerebellum become very active during complex movements. Anatomy studies have shown that these regions are primarily connected with areas of the cerebral hemispheres that are involved in planning actions rather than the actual execution of these movements. Thus it appears that as our cerebral cortex (or cerebrum in the picture) evolved to produce more complex actions, so too did the cerebellum and basal ganglia.

2. Learning new movement skills.

The basal ganglia and cerebellum are obviously essential for the production of skilled movement. But what about motor learning? Are these structures essential for the storage and retrieval of the motor memories that allow us to develop and retain new skills? The standard neurology textbook emphasizes that both the basal ganglia and cerebellum are critical for motor learning. Indeed, one notion of skill is that, with practice, memories shift from the cortex to the subcortex, allowing us to perform the action with minimal demands on the higher mental functions that the cerebrum provides such as attention and conscious control. By this view, we can walk, chew gum, and talk at the same time because the ancient subcortical parts of the brain are sufficient to control such overlearned movements.

We have spent a good deal of time over the past five years re-examining this idea. The motivation for our work was the recognition that the term motor learning covers a broad range of phenomena. For example, learning how to use a pair of chopsticks is quite different than learning how to type on a computer. The chopsticks require learning how to balance the opposing forces generated by the fingers on one hand. Typing requires learning the layout of the keyboard and then being able to make rapid transitions between different finger movements. Recognizing these differences has led us to compare different types of skills, asking how damage to either the basal ganglia or cerebellum might affect performance on these skills.

The most interesting result here has been the discovery that certain types of learning actually remain unaffected by cerebellar ataxia and Parkinson's disease. This conclusion is based on a set of experiments we've conducted in which participants are asked to produce a sequence of movements, either with their fingers or arms. Individuals with ataxia are slower than neurologically healthy individuals on such tasks. However, if the movements form a pattern that repeats over time, they show the same degree of improvement as our control participants. There is one important caveat here for the individuals with ataxia. Their ability to learn the sequences is hampered when the demands in making the movements themselves is difficult; for example, if the location of the movement is indicated by the color of a stimulus. Our hypothesis is that the processes for sequence learning are unaffected by pathology in the cerebellum or basal ganglia, an idea that is consistent with the fMRI work pointing to a role of the left hemisphere of the cerebral cortex in sequencing. The cerebellum is, however, important for helping produce the movements efficiently. If this function is compromised, then the cortical processes for sequence learning can not operate properly.

3. The role of the cerebellum in predicting the future.

Those of you who have worked with us for a number of years know that we frequently study rhythmic movements. While we recognize that those tapping studies may be tiresome, they have proved essential for establishing that the cerebellum acts as an internal clock, at least for time periods up to a few seconds. Precise timing in this range is critical for skilled movements. Throwing a ball accurately requires temporally coordinating the rotation of the arm with the release of the ball by the wrist.

Timing is one way in which the brain anticipates the future. Our minds are not fixed in the immediate present. Rather, we are constantly taking in information from the environment to make educated guesses about what will occur in the future: Will we be able to cross the street without being hit by the approaching car? When should we start slowing down a movement so that we do not knock over the glass of water? In one of our recent projects, we looked at this ability to anticipate the future in terms of perception rather than action. For this study, participants listened to a series of tones. Most of the tones occurred with in a rhythmic pattern, generated from a fixed position in space with a constant loudness and pitch. On rare occasions, however, the tone deviated from this standard pattern. It might be longer or shorter than normal, or it might have a different loudness, pitch, or come from a new location. In this way, we created a situation in which we violated participants' expectations of the future. We used electroencephalography (EEG) to measure the neural response to these violations. Our interest here was to determine if the cerebellum was important for all forms of prediction, or whether its' predictive functions were specific to timing. The results were generally consistent with the latter hypothesis. People with ataxia showed a delayed neural response when the duration of the tones was altered, but not when the tone came from an unexpected location or was of an unexpected pitch. Thus, it appears that the cerebellum helps generate predictions of the time of sensory events. This function may well relate to the difficulties people with ataxia have in generating rhythmic movements (those tapping studies, again!). The problem may be more related to a difficulty in predicting the sensory consequences of the movement rather than in controlling the movement or muscles. We are now conducting new studies to look more carefully at the sensory contributions to coordination. While we speak of ataxia and Parkinson's disease as movement disorders, it may turn out that a large part of the problem is related to anticipating and integrating sensory information with motor commands.

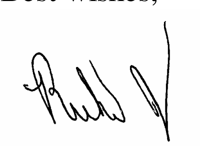
4. Overview of lab personnel

We have had several new additions to the lab in the past year. Many of you have probably met or spoken with Nola Klemfuss, the lab coordinator. Nola replaced Andrea Weinstein last summer. Andrea moved to San Francisco and is now working at UCSF. We have three energetic new graduate students, Dav Clark, Becca Stoloff, and Peter Butcher. You may notice some of Dav’s juggling equipment sitting around the lab, always a good distraction. Peter was a competitive snowboarder at UCSD, and Becca is an avid bicyclist. We have a new post doc in the lab, Arne Ridderikhoff, who comes to us from Amsterdam. Continuing with the international flavor, two visiting professors are with us this year, Ludovica Labruna from Italy and Miguel Fernandez Olmo from Spain. These newcomers join the "senior" grad students of the lab, John Schlerf, Flavio Oliveira, and Jing Xu. While the new comers bring a lot of fresh ideas and new directions, it also means that some of the "old guard" have left us. Most notably here is that Bekki Spencer, her husband Jim, and their two young daughters moved to New England. Bekki and Jim are now first year professors at the University of Massachusetts and are doing great starting their own labs.

I hope this newsletter is useful in providing you with an overview of the general questions addressed by our research program and also some details about the specific studies you may have participated in over the past year. I, or any of the members of the lab, are always happy to answer any questions or provide additional information. All of our results are reported in scientific journals and I've listed below a few of the ones from this past year. These reports are available for free from our website (and if you don't like to use the WEB or download files, we are happy to send you copies). I will warn you that the reports are written at a technical level and don't make for the most exciting reading to someone outside the fields of neuroscience and neurology. I have also listed some websites that have provided press reports on our work over the past few years.

Let me close by thanking you once again for your time and energy. We are extremely grateful for your participation and look forward to continue to work with you in the coming year. While we know that the work doesn't really offer any medical benefits to you, we hope that there is a personal satisfaction from knowing that your participation contributes to scientific progress. Your willingness to be part of these studies is an essential part of our efforts to understand the mysteries of the brain. Neurological disorders present an extreme challenge for each individual— coping with fluctuating symptoms, having to work hard to learn new skills, and keeping an eye out for new treatments and developments. They also provide a rare opportunity for researchers to explore how damage to the human brain affects various aspects of our mental and physical life.

Best wishes,



Richard Ivry
Professor
Director, Institute of Cognitive and Brain Sciences

p.s. We are always looking for new participants, including individuals who have not had any neurological problems. These individuals can serve as "controls" to compare with the performance of our participants who have had neurological problems. Please pass on my contact information or card to anyone who might be interested.

Contact Information:

Department of Psychology
University of California
Berkeley, CA 94720 USA

email: ivry@socrates.berkeley.edu lab: nklemfuss@berkeley.edu
phone: 510-642-7146 lab: 510-642-0135
webpage: http://socrates.berkeley.edu/~ivrylab/

Recent Scientific Reports (that can be downloaded from our lab's website):

Spencer, R.M.C. and Ivry, R.B. (in press). Sequence learning is preserved in individuals with cerebellar degeneration when the movements are directly cued. Journal of Cognitive Neuroscience.

Ell S.W. and Ivry R.B. (2008). Cerebellar pathology does not impair performance on identification or categorization tasks. 14:760-70.

Ghajar, J. and Ivry, R.B. (2008). The predictive brain state: Timing deficiency in traumatic brain injury? Neurorehabilitation and Neural Repair, 22, 217-227.

Ivry, R.B. and Schlerf, J.E. (2008). Dedicated and intrinsic models of time perception. Trends in Cognitive Science., 12, 273-280.

Moberget, T., Karns, C.M., Deouell, L.Y., Lindgren, M., Knight, R.T., and Ivry, R.B. (2008). Detecting violations of sensory expectancies following cerebellar degeneration: A mismatch negativity study. Neuropsychologia, 46, 2569-2579.

Spencer, R. M. C., Gouw, A., & Ivry, R. B. (2007). Age-related decline of sleep-dependent consolidation. Learning and Memory, 14, 480-484.

Spencer, R.M.C., Verstynen, T., Brett, M., and Ivry, R.B. (2007). Cerebellar activation during discrete and not continuous timed movements: An fMRI study. NeuroImage, 36, 378-387.

Cools, R., Ivry, R.B., and D'Esposito, M. (2006). The human striatum is necessary for responding to changes in stimulus relevance. Journal of Cognitive Neuroscience, 18, 1973-1983.

On-line course on Cognitive Neuroscience: The University is now posting audio copies of our lectures. You can follow along this semester at (or first download to your IPod!):

-Web cast (audiotaped lectures): http://webcast.berkeley.edu/course_details_new.php?seriesid=2008-D-16072|2008-D-74381&semesterid=2008-D

or, simply go to Webcast.berkeley.edu and under courses, select Cognitive Science C127, Psychology C127

- If you want to see the visual aids, my lecture notes are available here: http://socrates.berkeley.edu/~ivrylab/psych127_2008/lectures/