Microsensors, Implantable Devices and Rodent Surgeries for Biomedical Applications
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Hello everyone, and welcome back to our session on Rodent Behavioral Setups. This will likely be our final session focusing on the neural engineering aspects of surgery and behavioral setups, marking the conclusion of our neural engineering course. Today, we will delve into a particularly significant behavioral model: the Parkinsonian model.

In our previous session, we covered the stroke model, exploring its definition, clinical features, experimental setup, relevant behaviors, and analysis techniques. Now, we will apply a similar approach to understanding Parkinsonism. This model is widely utilized in both pharmacology and neural engineering research. In pharmacology, it serves as a platform for drug trials and the discovery of new medications. In neural engineering, it is instrumental for evaluating brain-computer interface devices and understanding the complexities of the brain's motor control systems.

Our focus today will be on the foundational aspects of the Parkinsonian model, which you can build upon and modify according to your specific research questions. We will start by defining Parkinson's disease and exploring its pathophysiology, laying the groundwork for understanding how to replicate key aspects of this condition in rodent models.

Unlike stroke, which is an acute and often emergent condition, Parkinson's disease is a progressive disorder characterized by the gradual degeneration of nerve cells in a specific brain region called the substantia nigra. This degeneration leads to impaired movement control. It's important to understand that this neuronal loss is not primarily due to ischemia, or lack of blood supply, as seen in stroke. While blood flow might play a role, the primary cause of degeneration in Parkinson's is different, involving various factors that we'll discuss in upcoming slides.

The substantia nigra, located within the basal ganglia, plays a critical role in regulating movement. The basal ganglia, in turn, is a complex network of brain structures involved in various functions, including motor control, learning, and reward processing. The intricate anatomy and physiology of the basal ganglia contribute to the complexity of Parkinson's disease, making it a rich area of research for understanding how the brain orchestrates smooth and coordinated movements.

By exploring the fundamentals of Parkinson's disease and its underlying mechanisms, you'll gain a deeper appreciation for the challenges and opportunities associated with modeling this condition in rodents. Understanding the key features and pathophysiology will guide you in designing and executing experiments that accurately reflect the human condition and contribute to the development of novel therapeutic interventions.

In the following sections, we will delve into the specific mechanisms of neuronal degeneration, the clinical manifestations of Parkinson's disease, and the behavioral assays used to assess motor dysfunction in rodent models. This comprehensive overview will equip you with the knowledge and tools necessary to navigate the complexities of Parkinsonian research and make meaningful contributions to this field.

The substantia nigra, as we'll delve into later, is a crucial component of the midbrain. The term "nigra" refers to its blackish appearance, stemming from the melanin pigment present in its neuronal cells. When examining a cross-section of the midbrain, you can observe a distinct band of dark coloration due to this melanin. Within the substantia nigra, specific divisions are particularly vulnerable to degeneration in Parkinson's disease.

The substantia nigra plays a pivotal role in movement control, but what exactly does that entail? Consider the act of reaching for a target. There's a specific distance to cover and an optimal trajectory to follow. Recall the Whishaw test in our rodent model, where the rat learns to navigate a path efficiently to reach the pellet, optimizing its movements over time. In humans, this concept extends to even more intricate actions, like a musician playing an instrument, requiring precise timing and coordination to produce the correct sequence of notes. These fine-tuned movements are orchestrated by two key brain structures: the basal ganglia and the cerebellum.

While the motor cortex ultimately sends signals to initiate movement, the basal ganglia and cerebellum act as modulators, fine-tuning and refining these signals to ensure smooth and coordinated execution. In Parkinson's disease, the degeneration of neurons within the substantia nigra disrupts this modulation process, leading to the characteristic motor symptoms associated with the condition.

This gradual and progressive neuronal loss significantly impacts the brain's ability to control movement. The disease is named after James Parkinson, a physician who first described it in an individual he referred to as having "the shaking palsy." This description captured the prominent tremor and overall motor impairment observed in patients. The disease now bears his name, Parkinson's disease, and its core features have been extensively characterized.

To help remember the cardinal manifestations of Parkinson's disease, we can use the mnemonic TRAP: Tremor, Rigidity, Akinesia, and Postural instability.

- Tremor: This is perhaps the most well-known symptom, characterized by involuntary shaking, often starting in the hands and progressing to other body parts.
- Rigidity: Patients experience stiffness and resistance to passive movement in their muscles, leading to a sense of being "trapped" in their own bodies.
- Akinesia: This refers to a difficulty initiating and executing movements, often manifesting as slowness and a reduced range of motion.

- Postural instability: Impaired balance and coordination increase the risk of falls, further impacting the quality of life for individuals with Parkinson's disease.

Understanding these core features allows us to identify and assess the behavioral manifestations of Parkinsonism in rodent models, paving the way for developing and evaluating potential therapeutic interventions.

Akinesia, a core feature of Parkinson's disease, refers to the loss or impairment of voluntary movement. Individuals with akinesia struggle to initiate and execute movements, even simple tasks like reaching for a glass of water can become challenging. This inability to move can occur even in the absence of rigidity, but often, rigidity is the underlying cause.

Tremor, another cardinal manifestation, is characterized by involuntary shaking. It commonly affects the hands and is classically described as a "pill-rolling tremor," resembling the motion of rolling a pill between the thumb and index finger. Tremor typically starts on one side of the body and may progress to the other side over time.

Rigidity, the third core feature, manifests as stiffness and resistance to passive movement in the limbs. To understand rigidity, we need to grasp the concept of muscle tone. Tone refers to the slight resistance encountered when passively moving a person's limb, even when they are relaxed. In Parkinson's disease, this tone increases significantly, affecting both the flexor and extensor muscle groups.

To differentiate between rigidity and spasticity, another condition associated with increased muscle tone, consider the following: Spasticity typically affects one muscle compartment more than the other. For example, in the upper limb, the flexor muscles might be stronger than the extensors, leading to a flexed posture, commonly seen in stroke patients. Rigidity, on the other hand, involves increased tone in both compartments, making it difficult to move the limb in any direction. This profound stiffness is often described as "lead pipe rigidity."

The combination of rigidity and akinesia can severely impact a person's posture and balance. The basal ganglia, which is affected in Parkinson's disease, plays a crucial role in maintaining posture, primarily through its influence on the axial muscles responsible for core stability.

Beyond these motor symptoms, Parkinson's disease can also lead to a range of non-motor symptoms, including cognitive impairment, depression, anxiety, sleep disturbances, and gastrointestinal issues. These diverse manifestations highlight the widespread impact of the disease on various aspects of a person's life.

Understanding the clinical features of Parkinson's disease is crucial for developing and evaluating effective treatments. By replicating these features in rodent models, researchers can gain valuable insights into the underlying mechanisms of the disease and test potential therapeutic interventions. Behavioral assays, such as those assessing motor

function, tremor, and rigidity, play a vital role in evaluating the efficacy of these interventions and advancing our understanding of Parkinson's disease.

In the next section, we will delve into the pathophysiology of Parkinson's disease, exploring the specific mechanisms that contribute to neuronal degeneration and the resulting motor dysfunction. This knowledge will further illuminate the rationale behind the behavioral assays and experimental approaches used in Parkinsonian research.

Axial muscles, as the name suggests, are those located around the vertebrae, similar to the paravertebral muscles in human anatomy. These muscles play a vital role in maintaining upright posture. Think of the muscles in your back - the latissimus dorsi, levator scapulae, trapezius, and, most importantly, the erector spinae muscles, along with the lumbar paraspinal muscles. They all work together to keep us standing tall.

When rigidity affects these axial muscles, it results in postural instability. The muscles become stiff and inflexible, hindering their ability to adapt and adjust to changing situations as needed for maintaining balance. This adaptability is typically orchestrated by the cerebellum and basal ganglia. However, when these structures are compromised, as in Parkinson's disease, postural control is impaired, leading to balance issues and an increased risk of falls.

Besides motor symptoms, Parkinson's disease can also manifest with a masked or expressionless face, characterized by infrequent blinking and a lack of emotional expressiveness. This is not due to a lack of desire to express emotions but rather an inability to control facial muscles due to rigidity. Additionally, patients often exhibit a forward tilt of the trunk, reduced arm swing, slightly flexed hips and knees, and a distinctive gait disturbance known as a festinating gait. This gait is characterized by short, shuffling steps, contributing to balance problems and a tendency to fall forward, often resulting in head injuries.

Now let's explore the pathophysiological changes that occur in the brain in Parkinson's disease. While we won't delve into exhaustive detail, we'll cover enough to provide a solid foundation. If your research focuses specifically on the Parkinsonian model, further in-depth study is highly recommended. However, for those primarily interested in neural engineering and implants, this basic understanding should suffice.

In Parkinson's disease, the substantia nigra is the primary site of pathology. Recall that the substantia nigra is part of the midbrain. Let's revisit the axial section of the human brain to visualize its location. You'll see the midbrain, pons, and medulla oblongata, collectively known as the brainstem. Above the brainstem lies the cerebellum, and further above, the cerebrum. This, in essence, is a simplified overview of the brain's anatomy.

Zooming into the midbrain, we find the substantia nigra, characterized by its dark pigmentation due to melanin. Within this structure, specific groups of neurons are particularly susceptible to degeneration in Parkinson's disease. These neurons produce

dopamine, a neurotransmitter crucial for regulating movement and reward pathways in the brain.

The loss of dopamine-producing neurons in the substantia nigra disrupts the delicate balance of neurotransmitters within the basal ganglia, leading to the characteristic motor symptoms of Parkinson's disease. The basal ganglia, a complex network of interconnected structures, relies on a precise interplay of dopamine and other neurotransmitters to function optimally.

By understanding the anatomical and neurochemical underpinnings of Parkinson's disease, we can better appreciate the challenges involved in modeling this condition in rodents. Replicating the key features and pathophysiological changes in animal models allows researchers to investigate the disease mechanisms, test potential therapies, and ultimately develop effective treatments for this debilitating condition.

The substantia nigra, located in the midbrain and characterized by its melanin pigmentation, plays a crucial role in movement control. However, in Parkinson's disease, this region undergoes degeneration, leading to the characteristic motor symptoms. While the exact causes of this degeneration remain an area of active research, several factors contribute to its onset and progression.

Although a genetic predisposition exists, not all individuals with Parkinson's disease have a clear genetic link. As people age and encounter environmental toxins, misfolding of a protein called alpha-synuclein can occur. Alpha-synuclein is normally present in neurons and plays a role in neurotransmitter transport. However, misfolding causes these proteins to clump together, forming aggregates known as Lewy bodies, which also contain neuromelanin deposits.

The accumulation of Lewy bodies triggers an inflammatory response and mitochondrial dysfunction, leading to the release of reactive oxygen species. These reactive molecules cause oxidative damage to DNA, lipids, and proteins within the neurons. Additionally, dopamine metabolism is disrupted, further compromising neuronal function. Ultimately, these processes culminate in programmed cell death, or apoptosis.

This cascade of events initiates a progressive and unfortunately irreversible decline in neuronal function. Once the process begins, it spreads to other brain regions, resulting in the diverse clinical manifestations of Parkinson's disease.

Now that we've explored the pathophysiological mechanisms, let's delve into the neural circuitry involved. We've touched upon the anatomy and the pathological changes, but to truly comprehend the manifestations of Parkinson's disease, we need to understand the intricate workings of the basal ganglia. This complex three-dimensional structure lies at the core of the human brain and plays a central role in movement control.

Understanding the circuitry of the basal ganglia is not only crucial for comprehending the targets for drug delivery in creating Parkinsonian models, but it's also essential for

identifying potential sites for neural implants used in deep brain stimulation therapies. We'll encounter terms like globus pallidus, subthalamic nucleus, substantia nigra, and striatum, so familiarizing ourselves with these structures and their interconnections is essential. We'll break down the complex circuitry into simpler terms to grasp its organization and function.

The basal ganglia neural circuitry consists of two primary pathways: the direct pathway and the indirect pathway. These pathways work in concert to regulate movement initiation and suppression. Disruptions in these pathways, caused by the degeneration of dopamine-producing neurons in the substantia nigra, lead to the motor symptoms observed in Parkinson's disease.

Let's delve deeper into how these neural networks operate, focusing on the motor system network. This network comprises primary and secondary motor areas, interconnected with the sensory cortex. Together, they form the corticospinal tract, which descends from the brain into the spinal cord, ultimately enabling movement. However, it's crucial to recognize the neuromodulatory roles of the basal ganglia and cerebellum, as disruptions within these structures can lead to various clinical manifestations and pathological conditions.

To understand how the higher centers in the brain regulate muscle tone, let's revisit the spinal cord's anatomy. The spinal cord has a dorsal horn responsible for sensory input and a ventral horn containing alpha and gamma motor neurons. Alpha motor neurons are the final common pathway for motor output, receiving input from interneurons and transmitting signals to muscle fibers, resulting in muscle contraction.

Several tracts influence alpha motor neuron activity and, consequently, muscle tone. The corticospinal tract, originating from the motor cortex, is one such tract. Others include the reticulospinal tract from the reticular activating system, the rubrospinal tract from the red nucleus in the midbrain, and the vestibulospinal tract from the vestibular nuclei in the brainstem.

The regulation of muscle tone is a dynamic process. Higher brain centers, based on information from the motor cortex and associative areas, determine when and how to adjust muscle tone to facilitate movement. The cerebellum plays an indirect role in this process by sending feedback to the brain, contributing to motor modulation within the basal ganglia. The final output, after processing in the basal ganglia, is transmitted through the corticospinal tract to the spinal cord, ultimately influencing muscle tone and enabling movement.

The basal ganglia achieves this modulation through two distinct pathways: the direct pathway and the indirect pathway. Let's start by examining the direct pathway. It's called "direct" because it forms a relatively simple loop, where information flows from the motor cortex to the basal ganglia, undergoes processing, and then returns to the motor cortex for further modulation before descending to the spinal cord.

The key players in this pathway are the motor cortex, striatum, globus pallidus internus (GPi), and thalamus. The striatum, composed of the caudate nucleus and putamen, receives input from the motor cortex. It then sends inhibitory signals to the GPi. The GPi, in turn, inhibits the thalamus. Finally, the thalamus sends excitatory signals back to the motor cortex, completing the loop.

In essence, the direct pathway facilitates movement by disinhibiting the thalamus, allowing it to excite the motor cortex. This excitation promotes the initiation and execution of voluntary movements.

So, these two structures, the caudate and putamen, collectively form the striatum. The striatum sends inhibitory signals to both the internal globus pallidus (GPi) and the substantia nigra pars reticulata (SNr). It's important to note that this inhibitory influence originates from the striatum.

Let's break down the sequence of events: The motor cortex stimulates the striatum. The striatum, in turn, inhibits the GPi and SNr. These structures, when active, send inhibitory signals to the thalamus. However, the connection from the thalamus to the cortex is excitatory. In its resting state, the thalamus has a tonic, or continuous, excitatory influence on the cortex.

This tonic excitation is kept in check by the double inhibition exerted by the basal ganglia. It acts as a regulatory mechanism, preventing overshooting of movements. For instance, when reaching for a ball, this inhibitory influence ensures that the movement is precise and doesn't go beyond the intended target.

The ultimate output of the direct pathway, however, is excitatory. This is because the striatum inhibits the inhibitory neurons in the GPi and SNr, effectively releasing the thalamus from inhibition. Thus, the direct pathway indirectly facilitates movement by modulating the tonic inhibition from the globus pallidus.

The direct and indirect pathways work in harmony, with one facilitating movement and the other inhibiting it. This delicate balance is crucial for achieving smooth and coordinated movements. Disruptions in this balance, as seen in Parkinson's disease, lead to the characteristic motor symptoms.

Now, let's explore the indirect pathway, which introduces an additional component: the subthalamic nucleus (STN). The STN exerts a tonic inhibitory influence on the thalamo-cortical output, which, as we know, is excitatory. This inherent inhibition further refines movement control.

The indirect pathway begins similarly to the direct pathway, with the cortex sending impulses to the striatum. However, instead of projecting directly to the GPi, the striatum sends signals to the globus pallidus externus (GPe). The GPe then inhibits the STN. The STN, in turn, excites the GPi. Finally, the GPi inhibits the thalamus, reducing its excitatory output to the motor cortex.

This indirect route, with its additional inhibitory connection through the STN, ultimately serves to suppress movement. The STN's primary function is to dampen or inhibit ongoing motor activity. Therefore, we can conclude that the indirect pathway is inhibitory in nature, while the direct pathway is excitatory.

The intricate interplay between these two pathways allows for precise control over movement initiation, execution, and termination. The balance between facilitation and inhibition ensures that movements are purposeful, accurate, and well-timed. In Parkinson's disease, the loss of dopamine disrupts this balance, leading to a predominance of the indirect pathway's inhibitory influence. This results in the hallmark symptoms of bradykinesia (slowness of movement), akinesia (difficulty initiating movement), and rigidity.

Understanding the complexities of the basal ganglia circuitry and the interplay between the direct and indirect pathways is fundamental for comprehending the pathophysiology of Parkinson's disease and developing effective therapeutic strategies. By targeting specific components of these pathways, researchers aim to restore the balance between facilitation and inhibition, ultimately improving motor function in individuals with Parkinson's disease.

This critical balance between facilitation and inhibition is maintained through the dynamic interplay of the direct and indirect pathways. So, what exactly goes awry in Parkinson's disease? Let's examine the contrasting circuitry between normal and Parkinsonian states.

Recall the illustrative diagram depicting the striatum, globus pallidus externus (GPe), and subthalamic nucleus (STN). Remember, the STN has an inherently inhibitory influence on the thalamo-cortical output, which drives movement. In Parkinson's disease, the inhibitory output of the STN increases unchecked, leading to a reduction in the thalamo-cortical drive and ultimately resulting in rigidity, akinesia, and tremors.

Let's dissect this further. The substantia nigra compacta (SNc) plays a crucial role by sending excitatory signals to D2 receptors on neurons within the indirect pathway. However, in Parkinson's disease, the SNc undergoes degeneration, leading to a loss of these excitatory signals. This loss diminishes the influence on the GPe, which normally inhibits the STN. With reduced inhibition from the GPe, the STN becomes overactive, exerting excessive inhibitory influence on the thalamus. Consequently, the thalamo-cortical output decreases, resulting in the hallmark motor symptoms of Parkinson's disease.

In essence, the degeneration of the SNc disrupts the balance between the direct and indirect pathways, tipping the scales towards excessive inhibition. The unchecked activity of the STN suppresses movement, leading to rigidity, akinesia, and the emergence of tremors due to the oscillatory imbalance between the facilitatory and inhibitory pathways.

To summarize the pathophysiology, remember that the degeneration primarily affects the substantia nigra compacta, leading to a loss of dopaminergic input to the striatum. This loss disrupts the delicate balance within the basal ganglia circuitry, resulting in the overactivity of the subthalamic nucleus and subsequent suppression of movement.

Now, let's explore how we can replicate this neuronal loss and the associated dopaminergic pathway dysfunction in rodent models. The substantia nigra compacta is a key source of dopamine, which acts on D2 receptors in the striatum, particularly those involved in the indirect pathway. The loss of this dopaminergic signaling is central to the development of Parkinsonian symptoms.

Several approaches can be employed to induce neuronal loss and create Parkinsonian models in rodents. One method involves direct toxicity, where agents are injected to target mitochondria and induce oxidative stress, excitotoxicity, and ultimately apoptosis, leading to dopaminergic cell death. Another approach utilizes substances like lactocysteine to promote the formation of Lewy bodies and inclusion bodies, mimicking the pathological hallmark of Parkinson's disease.

Additionally, genetic manipulations can be employed to create rodent models that exhibit Parkinsonian-like features. For instance, by knocking out specific genes involved in dopamine production or metabolism, researchers can induce dopaminergic dysfunction and observe the resulting behavioral changes.

These various approaches offer valuable tools for investigating the mechanisms underlying Parkinson's disease and evaluating potential therapeutic interventions. By carefully selecting and implementing appropriate models, researchers can gain crucial insights into the complex pathophysiology of this disorder and contribute to the development of effective treatments.

If your research aims to investigate the creation of inclusion bodies, the lactocysteine-induced model might be the most suitable. However, if your focus is solely on dopaminergic cell death, then using neurotoxic agents could suffice. However, to create a model that closely mirrors the human brain's pathophysiology, particularly the progressive nature of neurodegeneration, it's advisable to consider transgenic or non-transgenic alpha-synuclein models.

These models involve injecting specific viruses to alter the conformation of alpha-synuclein, leading to the formation of toxic protofibrils and fibrils. This process closely resembles the pathological events observed in the human brain affected by Parkinson's disease. While our understanding of Parkinson's is constantly evolving, with new theories and toxic agents emerging, these models currently offer the closest approximation to the human condition. They are invaluable for researchers seeking to unravel the intricate mechanisms of the disease and develop targeted therapies.

However, if your primary goal is to study the manifestations of Parkinsonism, then utilizing a toxic agent like 6-hydroxydopamine (6-OHDA) might be sufficient. This

model is relatively straightforward, involving a stereotactic injection of the toxic agent directly into the basal ganglia. It reliably induces dopaminergic cell death and the subsequent motor deficits associated with Parkinsonism.

Various models exist across different species, each with strengths and limitations. Rodent models offer convenience and cost-effectiveness, while primate models provide a closer approximation to the human brain and behavior. Additionally, simpler organisms like Drosophila (fruit flies) can be utilized for high-throughput genetic screening and studying fundamental disease mechanisms. The choice of model depends on the specific research question and the desired level of complexity and translational relevance.

Now let's take a closer look at the rodent basal ganglia, particularly its anatomical organization. While the rodent brain is less complex than the human brain, it still possesses structures that correspond to those found in the human basal ganglia. These include the caudate-putamen (striatum), globus pallidus externus (GPe), globus pallidus internus (GPi), subthalamic nucleus (STN), and substantia nigra pars compacta (SNc) and pars reticulata (SNr).

Understanding the anatomical correspondences between the rodent and human basal ganglia is crucial for interpreting experimental findings and translating them to the human context. It also aids in designing targeted interventions, such as deep brain stimulation, which aim to modulate specific structures within the basal ganglia circuitry.

So, all these components in the rodent brain are available to effectively mimic what happens in the human brain during Parkinson's disease. The example we've been discussing involves the use of 6-hydroxydopamine (6-OHDA), an excitotoxic agent that can be injected into the striatum. This injection leads to changes in the volume of specific nuclei within the basal ganglia, resulting in the loss of dopaminergic neurons. Although these changes may not be grossly visible, they significantly impact the functioning of the dopaminergic pathways.

For this session, we'll focus solely on the 6-OHDA model, a relatively straightforward and commonly used model for inducing Parkinsonism in rodents. The surgical procedure is relatively simple, involving the use of a Hamilton microsyringe with a 10-microliter capacity. After stabilizing the rat's head, a small twist drill hole is created, and the Hamilton syringe cannula is carefully inserted into the target brain region, either the striatum or the medial forebrain bundle.

Targeting the striatum leads to partial dopaminergic loss, making it suitable for inducing partial Parkinsonism. On the other hand, injecting 6-OHDA into the medial forebrain bundle results in a more significant loss of dopaminergic neurons and produces complete Parkinsonism. Remember, when targeting specific brain regions, it's crucial to utilize stereotactic coordinates to ensure accurate placement of the injection.

Once the 6-OHDA is injected, a waiting period of approximately 3 to 4 weeks is necessary for the Parkinsonian features to manifest. This allows time for cell death to

occur and for subsequent changes within the basal ganglia to unfold, ultimately leading to the observable clinical features of Parkinsonism.

Now that we've covered the target regions and the drug agent (6-OHDA), let's discuss the various ways to assess the manifestation of Parkinsonism in rodent models. Characterizing the behavioral changes is critical, especially when evaluating the effects of drug agents or neural implants aimed at modifying these clinical manifestations. To accomplish this, it's essential to familiarize yourself with the appropriate behavioral apparatus and assays. In our next session, we will focus on selecting the right apparatus for assessing Parkinsonian behaviors in rodents.

Before we conclude, let's recap the key points. We've discussed the definition and pathophysiology of Parkinson's disease, emphasizing the role of alpha-synuclein misfolding, Lewy body formation, and the subsequent neuronal death. We've also explored different approaches to creating Parkinsonian rodent models, including the use of toxic agents and transgenic or non-transgenic alpha-synuclein models. Additionally, we've highlighted the anatomical correspondences between the rodent and human basal ganglia, laying the foundation for understanding the neural circuitry involved in movement control.

Remember, the choice of model depends on your specific research questions and objectives. Whether you aim to study the molecular mechanisms of the disease, evaluate potential therapies, or investigate the impact of neural implants, selecting the appropriate model is crucial for obtaining meaningful and translational results.

In our next session, we will delve into the world of behavioral assays for Parkinsonian rodent models. We will discuss various assays designed to assess motor dysfunction, tremor, and other relevant behavioral phenotypes. By understanding the principles and applications of these assays, you'll gain the knowledge and tools needed to design and conduct robust behavioral experiments in your own Parkinsonian research.

Thank you for your attention today. We look forward to continuing our exploration of rodent behavioral setups in the next session. Until then, feel free to review the material and reach out if you have any questions.