Ready, Set, Neuro!

Kinesiology Lab Days

Presentation Notes

Introduction

Purpose

During this presentation, you will gain an understanding of response time under the lens of neuroscience. You will get a chance to investigate reaction and movement time with different stimulus modalities, Hick's Law, and Fitts' Law.

We will explore each topic in more depth, perform experiments related to the topics, identify the expected results, and have some group discussions.

Neuroscience

What is Neuroscience?

What is Neuroscience? **Neuroscience** is the multidisciplinary scientific study of the nervous system, ranging from disciplines in anatomy and physiology to math and computer science. In Kinesiology, we are specifically interested in connecting the neural networks to control of movement and human behaviour. Examples of movement or behaviours that we could examine include cycling, jogging, and throwing or catching a frisbee.

Neuroanatomy

In order to understand how our neural networks, control our movements, we need to know a little bit about neuroanatomy.

The human nervous system allows us to process information from our environment and respond to different signals. These signals can be referred to as **stimuli**, which are sensory events that evoke a bodily response. The nervous system has 2 main components: the central nervous system (CNS) and the peripheral nervous system (PNS).

The CNS consists of the brain and the spinal cord and is responsible for interpreting stimuli from our environment and determining the appropriate response. For example, if you were driving and came across a red light, your CNS would interpret the red-light stimulus and decide that you need to apply the brakes. The brain has multiple lobes. This allows the brain to process, organize, and store different types of information. For example, the occipital lobe is responsible for processing visual information, and the temporal lobe is responsible for processing auditory information.

The PNS functions to carry information to and from the CNS. The body has many networks of nerves that merge with the CNS and extend throughout the body. This allows for the transmission of information. We have sensory receptors all over our bodies that detect different stimuli and you can see that our nerves extend to every edge on the body to allow for communication between receptors and nerves. When receptors detect stimuli, they transmit information to **afferent** neurons. Afferent neurons then transmit the information to the CNS where it gets interpreted, and the response signal travels to the appropriate muscles or tissues via **efferent** neurons.

Response Time

Response to Stimuli

One way we measure the speed of the brain is by connecting a stimulus to a corresponding movement. This time measurement is known as Response Time. As you can see in this diagram, response time includes both reaction time and movement time.

Reaction time (RT) is the time it takes to *initiate* a movement (i.e., time between the onset of a stimulus and onset of muscle activation). In this baseball example, the stimulus, which could be seeing the baseball being thrown, travels to the athlete’s eye and is detected by photoreceptors on the retina (the back of the eyeball). The photoreceptors then send a message to the brain, and the brain interprets the signal and determines the appropriate response. Then, the brain sends a signal to the muscles telling them to activate so they can perform the required movement.

Movement time (MT) is the time between the onset of muscle activation and the completion of a movement. Once the signal from the brain reaches the muscles, the muscle fibers begin to contract. This leads to the player starting the movement of swinging the bat. In this scenario, movement time would end when the player has finished swinging the bat.

To summarize, reaction time is that time between the baseball being thrown and onset of muscle activation, and then movement time is the time between the onset of muscle activation and the follow through after hitting the ball. And as mentioned earlier, response time is the time it takes for both reaction time and movement time to occur.

Since we rely on muscle activation to identify the end of reaction time and the beginning of movement time, we need electromyography (EMG) equipment to accurately measure reaction time and movement time.

Electromyography

To measure the electrical activity of the nervous system activating a muscle, we used what is called “electromyography” or EMG. This is what the EMG signals we collect in the lab look like. In this experiment, the participant had to press a button as quickly as possible when a light flashed. The yellow line at the top represents the EMG for the muscle (it was the anterior deltoid in this experiment), the blue line represents the button being pressed, and the purple line represents the stimulus, which would be the light signal. Along the X-axis, is time in seconds and along the Y-axis, is signal amplitude measured in volts.

We collect data from muscles by attaching electrodes to the area of skin over the target muscle. At rest, the muscle is inactive and therefore the EMG signal (yellow line) would be relatively flat and stable. As you can see on the graph, at around the time the stimulus is introduced, the EMG signal starts spiking (or amplitude is increasing). This tells us that the muscle has been activated.

Therefore, reaction time begins when the stimulus is introduced, and ends when the muscle's EMG signal starts spiking. This period would represent our reaction time **(click to reveal Stimulus and Onset of Muscle Activation)**. We also know that movement time is the time between the onset of muscle activation and completion of the required movement or goal. This period would represent our movement time. Lastly, we know that response time is the total of reaction time and movement time together

Since we don't have any EMG equipment to show us when muscle activation starts, our reaction time experiments are technically going to be measuring our overall **response time**. However, when we're responding to different stimuli in the experiments, we will be performing the same movements, so our movement time won't really change. Thus, any differences we see in response times will be a result of differing reaction times. This will make more sense when we start doing the experiments

What Influences Reaction Time?

Reaction time can be influenced by the stimulus modality.
Stimulus modality refers to the form of the stimulus, and we have the ability to detect many different forms of stimuli. As seen on the right, some examples would include touch, sight, taste, sound and smell.

Speed of processing refers to how fast information can be detected (via transduction), moved and interpreted within the nervous system. The modality of the stimulus can affect the speed processing. This is because our sensory systems have different types of receptors and neural networks that sense stimuli and transduce information at different speeds.

What do you think is processed faster, visual or auditory stimuli?

There are different neural pathways for visual and auditory stimuli. The neural pathway for auditory stimuli is shorter than the pathway for visual stimuli. The receptors that sense auditory stimuli are called mechanoreceptors, and those mechanoreceptors are in closer proximity to the brain and therefore, the CNS. Auditory signals having less distance to travel can be an influence on the ability for them to be processed faster. However, other considerations include the number of connections in the brain required to process the stimuli, proximity to the brain and the complexity of the processing.

Experiment 1A: Visual Reaction Time

This is our first experiment, **Experiment 1A: Visual Reaction Time**. We will be testing reaction time for a visual stimulus.

Instructions:

1. Open the **Visual Reaction Time Test**
2. Click anywhere to start the test
3. When the screen turns green, click as quickly as you can
4. Collect 5 trials and record your results for each trial
5. Calculate your average and record on your data collection sheet

Experiment 1B: Auditory Reaction Time

This is **Experiment 1B: Auditory Reaction Time**, part 2 of experiment 1. Now, we are going to be testing reaction time for an auditory stimulus.

Instructions:

1. Open the **Auditory Reaction Time Test**
2. Check to make sure your sound is on
3. Click anywhere to start the test
4. When you hear a sound, click as quickly as you can
5. Collect 5 trials and record your results for each trial
6. Calculate your average and record on your data collection sheet

Expected Results: Visual vs. Auditory Stimuli

We had our team do Experiments 1A and 1B, and this graph represents the average results. As you can see, we have response time in milliseconds (ms) on the Y-axis, and we have our different stimulus modalities on the X-axis. Based on our results, the average response time was around 320 ms for the visual stimulus, and around 250 ms for the auditory stimulus. This difference in response time is due to differences in processing time between visual and auditory stimuli.

Expected Results: Visual vs. Auditory Reaction Time

Studies have shown that the average reaction time for an auditory stimulus is around 180 milliseconds, and the average reaction time for a visual stimulus is around 200-250 milliseconds. This is due to those differences in proximity to the central nervous system as well as the complexity of the two sensory modality pathways.

As mentioned earlier, the experiments we performed were truly measuring **response time.** However, since we were doing the same movement for both experiments, which was clicking the screen, movement time would stay relatively constant for both experiments. Therefore, the differences in the overall response time are due to the differences in reaction time. You will see this in the next experiment as well.

Discussion Questions

What phase(s) of response time is indicated by the onset of muscle activation?

Why does auditory reaction time tend to be faster than visual reaction time?

Hick's Law

What Influences Reaction Time

We talked about how different stimulus modalities can affect reaction time, but one of the other factors that can impact reaction time is **task complexity**. Tasks that require more cognitive effort can affect how fast we react and how well we perform. For example, a task that involves choosing between five possible responses will take more cognitive effort than a task that only has one possible response. More complex tasks will increase reaction time, and less complex tasks will decrease reaction time.

Another factor that can influence reaction time is the **predictability of a stimulus.** Knowing when a stimulus will appear will affect how fast you are able to react. A predictable stimulus will reduce reaction time, while an unpredictable stimulus will increase reaction time.

We will focus on task complexity for the next few slides of this presentation.

Hick's Law

Hick's Law is the principle relating task complexity to reaction time. Hick's Law states that reaction time will increase as the number of choices increases. Simply put, increased choices mean increased task complexity, which means increased processing time, and therefore, increased reaction time.

Hick's Law can be observed when we examine the differences between simple and choice reaction time.

Simple Reaction Time

Simple reaction time is the time it takes to respond to one stimulus with one corresponding response.

For example, at the start of a race when you hear the starting gun (stimulus), the only response is to start running.

Also, experiments 1A and 1B that we just performed would both be examples of simple reaction time. For each experiment, there was only one stimulus, which was the screen turning green for the first experiment, and the 'ring' sound for the second experiment. There was also only one corresponding response for each stimulus, which was clicking the screen.

Choice Reaction Time

Choice reaction time is the time it takes to respond to multiple stimuli that each elicit a different response.

For example, responding to a traffic light would involve choice reaction time. There are three different possible stimuli: red light, yellow light, and green light, and they each require a different response: stop, slow down, and go. Since the driver needs to decide the appropriate response for each stimulus, this would be a more complex task that requires more cognitive effort.

Like the stimulus modality experiments, tests like simple versus choice reaction time give us more insight into different aspects of information processing.

Experiment 2: SRT and CRT

This is **Experiment 2: Simple and Choice Reaction Time.**

Instructions:

1. Open **Simple and Choice Reaction Time Test**
2. Follow the instructions on the screen (you will perform the simple task first followed by the complex task)
3. Record your values for "response speed in simple task" and "response speed in choice task"

Expected Results: Simple vs. Choice Task

This is our team's results for the simple and choice tasks. As you can see on this graph, we have response time in milliseconds on our Y-axis, and our different task modalities on our X-axis. You'll also notice that our team's average response time for the choice task was longer than the simple task. The average response time was around 300 ms for simple task, and around 425 ms for choice task. These results were expected because we know that increased choices lead to increased decision making and processing time, and therefore an increased response time.

Expected Results: SRT vs. CRT

The results for this experiment are consistent with Hick's Law, which states that simple reaction time is faster than choice reaction time.

To further illustrate the effects of Hick's Law, imagine playing a whack-a-mole game and there is only one hole that the mole is popping out of. You should be able to quickly whack this mole. This would be an example of simple reaction time since there is only one place where the mole is appearing.

However, if there were six holes in this game, there are now several possibilities for where the mole might appear. You now need to process more options in order to accurately whack the mole, thereby increasing your reaction time. This would be an example of choice reaction time.

Discussion Questions

Why does an increased number of choices cause an increase in reaction time?

How many stimuli will be present in a simple reaction time task?

Fitts' Law

Movement Time

So far, we've been focusing on factors that can impact reaction time. Now, we're going to be focusing on factors that can impact movement time, which is the second component of response time.

Fitts' Law

Fitts' Law states that in general, the smaller the targets are, the longer our movement time will be, and the farther apart the targets are, the longer our movement time will be.

Movement time can be influenced by target width because wider targets tend to be easier to hit, and smaller targets tend to be more difficult to hit. Movement time can also be affected by amplitude because targets that are closer together require smaller movements, and targets that are far apart require larger movements.

Experiment 3: Fitts' Tapping Task

We are going to try out **Fitts' Tapping Task** to see how your movement time is affecting when targets become wider/narrower, and closer/further apart.

Instructions:

1. Open **Fitts' Tapping Task**
2. **Change # of trials to 5 and press start**
3. Click back and forth between the two targets (moving to click blue target)
4. Values will appear at the end of the experiment: A – amplitude, W – width, MT – movement time
5. Record the **mean** movement time for each trial on your data collection sheet

Expected Results: Fitts' Tapping Task

There are two parameters to look at for the results of this experiment: movement amplitude and target width. We have movement time in milliseconds on our Y-axis, and amplitude on our X-axis. You'll also notice that for each amplitude, we have three different bars for each target width (narrow, medium, and wide).

Within each distance between bars grouping (5, 10, and 15 cm), you'll see that movement time decreases as the targets get wider. **(Click once to reveal arrows).** The narrow targets always have the longest movement time, followed by the medium targets, and then the wide targets. This is consistent with Fitts' Law which states that as targets increase in width, movement time decreases.

You'll also notice that movement time increases as the amplitude increases. (**Click once to reveal brackets and arrow).** This is also consistent with Fitts' Law which states that as amplitude increases, movement time increases.

Expected Results: Fitts' Tapping Task Movement Time

To summarize, it is expected that for Fitts' Tapping Task, the targets that were wider and closer together had the shortest movement time, and the targets that were narrower and farther apart had the longest movement time. This is referred to as a speed-accuracy tradeoff, because in order to be more accurate with tapping targets that are narrow and far apart, we need to sacrifice quick movement time.

Discussion Questions

Under which conditions would you expect to see the shortest movement time: targets are wide and far apart, targets are narrow and close together, or targets are wide and close together?

What will happen to your accuracy in the Fitts' Tapping Task if you decrease the speed in which you complete the task?

Automaticity

Automaticity is the ability to perform a task with little to no conscious control. Automaticity is a measure of learning. It shows that a skill has become automatic to the performer.

Thinking back to the traffic light example when we were discussing choice reaction time, it might take longer for a new driver to determine how to respond to a light changing. However for someone that has been driving a long time, they may not require as much conscious effort to decide how to respond to the stimuli.

How do we determine whether a task is automatic or not?

Measuring Automaticity: Dual Task Paradigm

To determine if a task is automatic, one method is to use the **Dual-Task Paradigm**.
Dual tasking is when a task is performed, and a second task is added. We often refer to this as multi-tasking. Multi-tasking occurs in everyday life, whether it be walking and chewing gum, listening to music while doing homework, or simply playing a sport.

The Dual-Task Paradigm states that if task 1 is automatic, response time should not increase despite the addition of task 2. If task 1 performance worsens with the addition of task 2, this tells us that task 1 may not be automatic.

This paradigm helps us to understand how different tasks can interfere with each other and what type of tasks require more attention and cognitive effort.

Experiment 4 Part 1: Single Task (ST)

Instructions:

This is **Experiment 4 Part 1: Single Task.**

1. Have the participant walk to the 10 m mark and time them with a stopwatch
2. Record their time on the recording sheet
3. Calculate gait speed by diving walking distance (m) by walking time (s), and record on the recording sheet

Take turns being the participant and experimenter. Round numbers to 2 decimal points.
Gait speed = walking distance (m) ÷ walking time (s)

Experiment 4 Part 2: Dual Task (DT)

Instructions:

This is **Experiment 4 Part 2: Dual-Task.**

1. Have the participant walk 10m while counting backwards from 100 by 7s (**should be focusing on counting**), and time them with a stopwatch
2. Record their time on the recording sheet
3. Calculate gait speed by dividing walking distance (m) by walking time (s)
4. Calculate percentage of dual-task cost using the dual-task cost equation

Take turns being the participant and experimenter. Round numbers to 2 decimal points.
Gait speed = walking distance (m) ÷ walking time (s)
Dual-Task cost = [(gait speed for DT – gait speed for ST) ÷ gait speed for ST] x 100

Expected Results: Single and Dual-Task Results

We had our team perform the Dual-Task activity, and these are the average results. As you can see, we have gait speed in m/s on our Y-axis, and the task types on our X-axis. You'll notice that gait speed was faster for the single task than the dual task. The average gait speed was around 1.02 m/s for single task, and around 1.88 m/s for dual task.

These results are expected because walking is not considered an automatic task. The Dual-Task Paradigm states that if a task is not automatic, the addition of a second task will worsen the performance of the first task, which is consistent with these results. When the cognitive task was added to the walking task, walking performance declined.

Expected Results: Dual-Task Paradigm

During the dual-task activity, you likely noticed that walking and simultaneously counting backwards had a negative impact on your performance. Since these activities interfere with each other, neither task can be considered automatic.

There are a lot of tasks that are not as automatic as we think. For example, walking is something we do every day, and many would think it requires little to no conscious control. However, studies show that when asked to perform different cognitive tasks while walking, like counting backwards, participants slow down. They also perform better on some of the cognitive tasks when they walk more slowly. This tells us that even tasks that seem simple and effortless can require some level of cognitive effort when dual tasking.

Discussion Questions:

What do errors tell us about automaticity in the context of the Dual-Task Paradigm?

What does the Dual Task Paradigm tell us about scenarios like texting and driving, where neither driving nor texting can be considered automatic?

Using Reaction Time in Balance Control

Earlier in this presentation, we mentioned how reaction time can be used to assess speed of processing.

In everyday life on several occasions, we have to process stimuli from our environment and make the appropriate movement. A prime example is regaining balance when we slip, trip, or are knocked off our feet.

At the University of Waterloo, we are interested in understanding the control of balance and how this control reflects health and disease. One of our researchers, Dr. Bill McIlroy is interested in RT when an individual loses their balance. Measuring RT in the muscles controlling the ankle allow us to assess how quick individuals can respond and regain their balance. A longer RT can be seen in older adults, which is one of the reasons why falls are more prevalent with our grandparents.

Here is a video showing Canadian icon, David Suzuki, visiting our Kinesiology labs and testing his balance on a moving platform. While on the moving platform, participants are hooked up to track brain and lower leg muscle activity using specialized equipment. **(play video from 9:55 to 12:20)**

Conclusion

Questions?

In this workshop, we've talked about reaction time, movement time and response time, and how they can be influenced. It's also important to understand *why* we should learn about these things. The data collected in these research studies at UW can give us more insight regarding how reaction time may vary among different populations. These findings can potentially be used to help prevent dangerous falls, especially in populations that are more prone to falls.

END OF PRESENTATION

Excel Data Collection File

The excel data collection file is a collaborative file to be shared with students during or after the presentation. The file contains tables and graphs that will automatically update as data is inputted. Students will input their own results. Please send the provided summary table to klabdays@uwaterloo.ca. Class averages will be displayed on the "Ready, Set, Neuro!" data dashboard and each school will be represented by a single average number. Averaging will maintain the anonymity of the data.

Discussion Questions

Q1: What phase(s) of response time is indicated by the onset of muscle activation?
A: Onset of muscle activity is indicates the end of reaction time and the beginning of movement time.

Q2: Why does auditory reaction time tend to be faster than visual reaction time?
A: This is due to the proximity of auditory receptors to the central nervous system. The neural pathway for auditory signals is shorter than the pathway for visual signals and less complex, and since they have less distance to travel, they can be processed faster.

Q3: Why does an increased number of choices cause an increase in reaction time?
A: As we mentioned on our Hick's Law slide, increased choices mean increased complexity, which will result in more processing time and higher cognitive demand. We know that the CNS acts as the interpreter of the body, and the CNS takes more time to process this information simply because there is more information to process.

Q4: How many stimuli will be present in a simple reaction time task?
A: Simple reaction time tasks will have only one stimulus with one corresponding response. If there is more than one stimulus with one possible response, this would fall into choice reaction time.

Q5: Under which conditions would you expect to see the shortest movement time: targets are wide and far apart, targets are narrow and close together, or targets are wide and close together?

A: We would expect to see the shortest movement time when targets are wide and close together. Fitts' Law states that movement time decreases as targets get wider and closer together. In that first condition, we would have to sacrifice some movement time to reach targets that are far apart since they require larger movements. In the second condition we would sacrifice movement time when we're trying to hit those narrow targets, since they're more difficult and the movements need more finetuning.

Q6: What would happen to your accuracy in Fitts' Tapping Task if you decrease the speed in which you complete the task?

A: If you decrease your movement speed, your accuracy will increase. This is the speed accuracy trade-off we mentioned earlier, so if you want a faster movement time, you'll need to sacrifice accuracy, if you want more accuracy, you'll have to sacrifice some movement time.

Q7: What do errors tell us about automaticity in the context of the Dual-Task Paradigm?

A: If a learner is making a lot of errors when multitasking, we can assume that at least one of the tasks being performed is not automatic. Increased errors can be indicative of a worsened performance, and the Dual-Task Paradigm states that if the performance of a task worsens with the addition of a second task, the first task is not automatic.

Q8: What does the Dual-Task Paradigm tell us about scenarios like texting and driving, where neither driving nor texting can be considered automatic?

A: The Dual-Task Paradigm gives us insight about how much our task performances can be impacted when we introduce a second task. Since driving is not automatic, the addition of a second task will substantially affect your ability to drive. It is important that we understand how dual-tasking can worsen our performance in non-automatic tasks so that we avoid dangerous situations like texting and driving.

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