Perception Lab 4: Reaction Time and Neural Circuitry

Background

We take many everyday actions for granted, from blinking our eyes to picking up a pencil to driving a car. Most actions, except for the simplest reflexes, involve a large amount of brain activity: receiving and processing sensory information, integrating and interpreting that information, and controlling of muscle activity to produce movements in response to the information. This lab allows you to discover that more complex tasks require longer processing time, reflecting the increased activity in the brain. We can then use a bit of 'Fermi mathematics' to estimate the number of synaptic connections for each task.

Reaction time is the amount of time required for the nervous system to receive and integrate incoming sensory information and then cause the body to respond. The simplest example of reaction time is the time required for a simple reflex to occur. In this lab, a relatively simple task will be used in place of a reflex response. In the first part of the lab, you will be required to deal cards randomly into two piles. This is a simple repetitive motor task involving a relatively uncomplicated neuronal circuit with few synapses, such as that shown in Figure 1. *Note: All the tasks described in this lab, even those involving random sorting, are more complex than the monosynaptic knee-jerk reflex described below.*

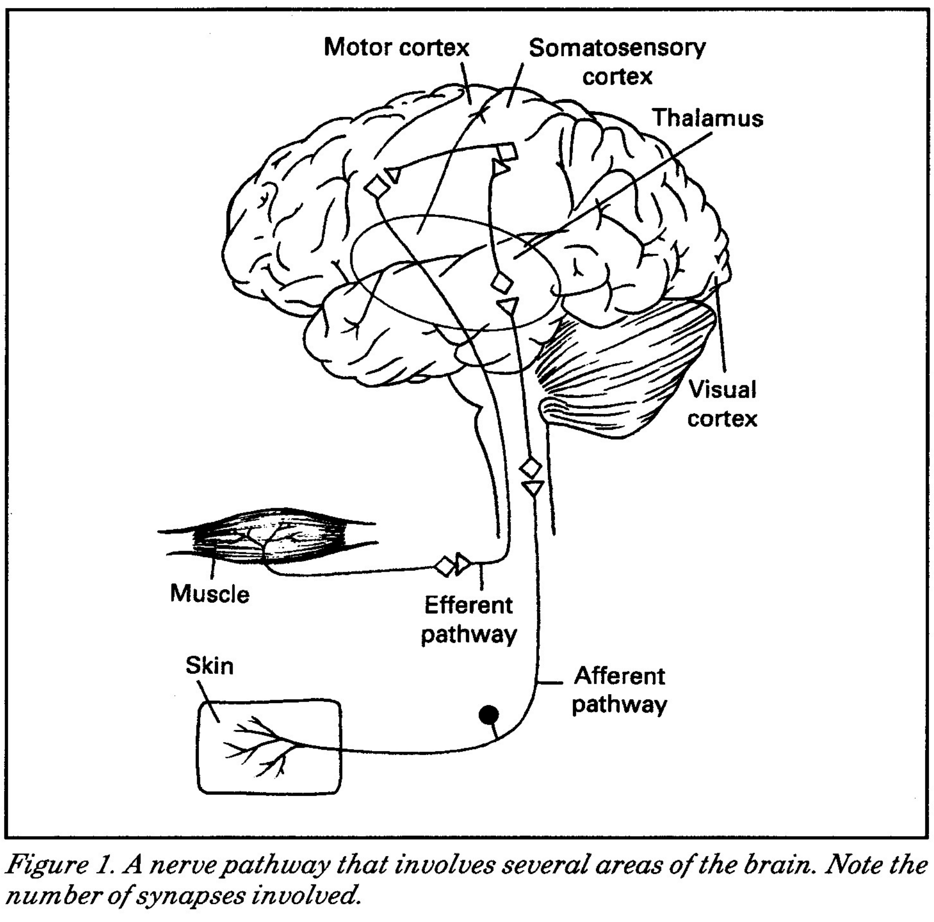

Figure 1. A nerve pathway that involves several areas of the brain. Note the number of synapses involved.

The procedure becomes more complicated in Task 2, as you will next separate the cards into two piles: one for red suits and one for black suits. The reaction time, or the time to complete the task, will increase for Task 2, as you now must process more information. The brain must differentiate between the red and black suits on the cards, then send a command to activate the appropriate muscles to move the arm and hand to the right spot for the cards. The information will be received by the brain in the *visual cortex* (see Figure 2) and sent to the *association cortex* where the sensory signal will be interpreted and associated with a memory of where to put the card.

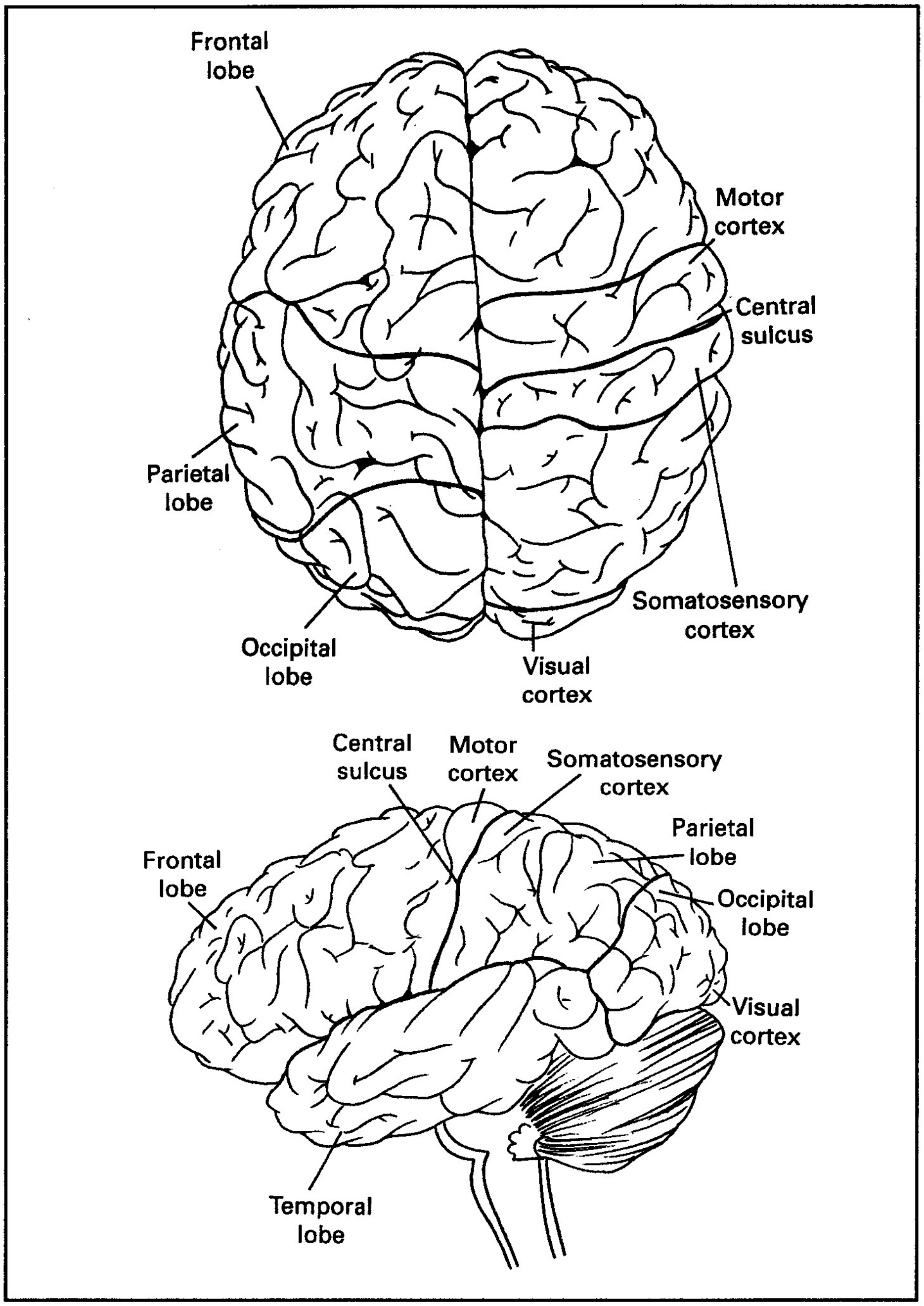

Figure 2. Major divisions of the human cerebral cortex: (a) dorsal view, (b) lateral view of left hemisphere.

This new information then goes to the motor cortex where it initiates a signal that is transmitted down the spinal cord and out to the muscles to move the arm and hand to place the card in the correct pile. The time required to make the distinction between red or black cards is called the *discrimination tim*e.

The simplest reflex involves only two neurons and one synapse *(monosynapti*c). This reflex is commonly observed as the knee-jerk reflex, which occurs when the tendon just below the kneecap is tapped. This stimulus in turn causes the muscle to contract, moving the leg. The reflex does not require any brain activity, as the circuitry is contained within the spinal cord itself. If one were to concentrate on holding the leg still, then the reaction time and degree of response would change. In a like manner, if the task is a simple rote memory task, like reciting the multiplication tables, then it can be done almost reflexively. If the task involves some discrimination process (thinking), then it will be even slower. If a distraction is introduced, such as dealing the cards into two piles while reciting multiplication tables, then the discrimination time and reaction time will both be increased.

Discrimination time will increase with the increased complexity of a task. As the task becomes more complex, more things must be considered and compared, allowing for more options and decisions to be made. In the brain this means more neurons are involved. Neurons communicate with each other through a synapse. It requires a minimum of 0.5 millisecond (msec) for the signal to cross a synapse (Guyton, 1991, p. 493) and cause some change in the activity of the second or postsynaptic neuron. Since the postsynaptic neuron is also receiving information from other neurons *(convergenc*e) it will take even longer to process all of the signals. See Figure 3.

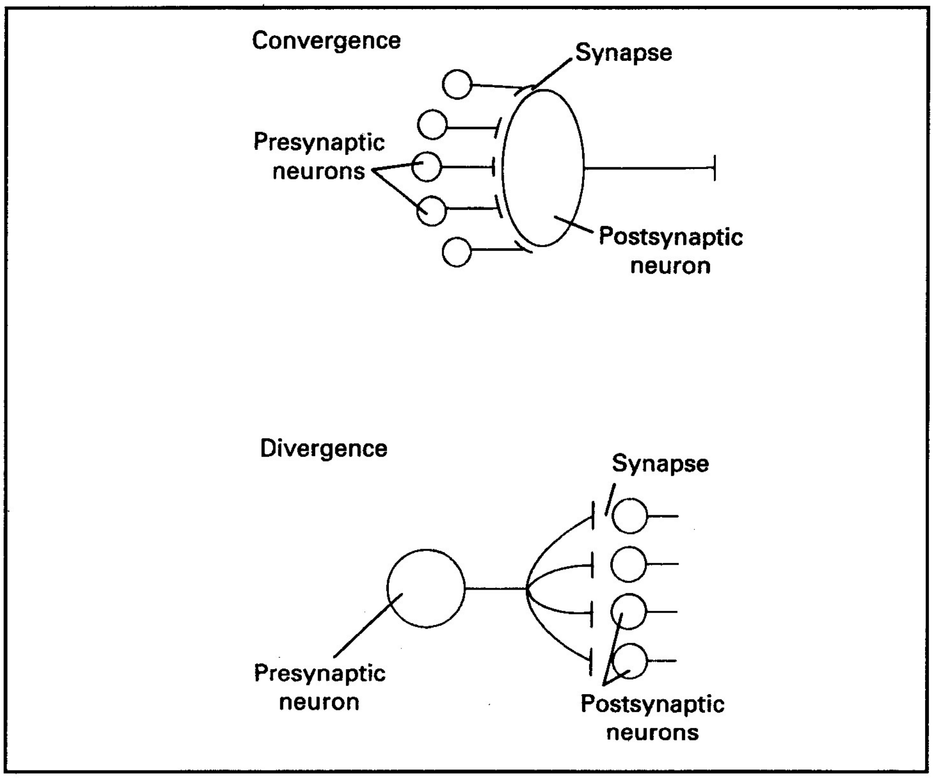

Figure 3. Convergence and divergence of neuronal signals.

This processing of the various signals is called *integratio*n. The signals from one neuron will influence the activity in the second neuron in one of two ways: (1) *excitatio*n, causing a new signal to be formed and passed on to other neurons, or (2) *inhibitio*n, preventing the formation of a new signal to be passed on to other neurons. Because a neuron is receiving a multitude of inputs from many other neurons, it will integrate all the inhibitory and excitatory information and the resultant action will be the sum of all the incoming information.

Protocol: Work in pairs. One person should act as the card sorter while the other as the timer and data recorder. For tasks 1 and 2, predict what results you expect (which will take longer). Develop a hypothesis for your prediction. A hypothesis should consist of an "if… then" statement. Generate a prediction and a hypothesis for tasks 3 and 4.

Task 1: Sorting cards ***randomly*** into two piles.

1. The card sorter should shuffle a full deck of cards.
2. When the timer tells the sorter to begin, the sorter should deal the deck of cards **randomly** (that is, without regard to suit, color etc) into two piles as quickly as possible.
3. The timer should note the time in seconds necessary to complete the task and record this number.
4. Repeat Steps 1 through 3 three times and average the four numbers.
5. Switch roles (the sorter should serve as timer and then timer as sorter) and repeat steps 1 through 4.

Task 2: Sorting cards into two piles — one red pile and one black pile.

1. Follow the same protocol as described for Task 1 except sort by color.
2. Remember to do this four times and to average the time for each sorter.

Task 3: Sorting cards ***randomly*** into four piles

1. Follow the same protocol as described for Task 1 except create four piles without regard to color, suit etc.
2. Remember to do this four times and to average the time for each sorter.

Task 4: Sorting cards into four piles — one for each suit (hearts, diamonds, clubs, spades)

1. Follow the same protocol as described for Task 1 except sort by suit.
2. Again, remember to do this four times and to average the time for each sorter.

<u>*Enter your averaged data into the class spreadsheet.</u>

Discussion: Analyze the data from the class spreadsheet and answer the following questions:

1. How does the time required to perform Task 1 compare with the time required to perform each of the following tasks? Support your answer with a sound rationale:

   - Task 1 vs. Task 2?
   - Task 1 vs. Task 3?
   - Task 1 vs. Task 4?

2. How would the time required to perform Task 3 compare with the time required to perform Task 4?
3. How would the time required to perform Task 2 compare with the time required to perform each of the following tasks? Give a one sentence rationale for each of your answers:

   - Task 2 vs. Task 4
   - Task 2 vs. Task 3

4. Which task took the greatest amount of time for the class?

5. Which task took the shortest amount of time for the class?

6. Did the experimental results and your predicted results match? If not, can you develop a plausible reason to explain why?

7. Subtract the Task 1 time from the Task 2 time and subtract the Task 3 time from the Task 4 time. What do these differences represent? Why does this difference exist?

As a class, we will then try to work through some rough mathematical calculations (Fermi math) to help us understand more about the neural circuitry involved in each of the tasks.

Some things to think about…

1. Is there a point at which reaction time can’t be shorter? Why or why not?

2. If a distraction occurs during the activity — such as loud noises, someone talking to the student, someone tapping a ruler on a desk, or music — would the reaction time change?

3. If someone performs some rote memory task, such as singing a song while performing a discrimination task, do you think the reaction time might be affected? Why?