1. The longest axon of a human motor neuron can be over a meter long, reaching from the base of the spine to the toe. The maximum distance a passive current will flow along a neuron is only about 1 millimetre. So, how does the neuron solve the problem of ensuring fast conduction over long distances?

ANS: in order to achieve the communication along 1 meter, we need both speed and a long-distance impulse. To be able to travel far, the signal gets propagated trough rapid polarizations and depolarizations on the axon's membrane. To do so certain regions (Nodes of Ranvier) aren't encapsulated with the myelin, allowing the opening and closing of certain ion channels with the outside of the cell. Those impulses are the Action Potential and thanks to the oligodendrocytes they get fast and really resistant to voltage losses.

The main properties of Action Potentials are:

1. Threshold for initiation: AP is only triggered when a certain amount of input stimuli, namely -55mV. This introduces a sort of threshold to mask out non-significant impulses.
2. Conducted without decrement: the impulse is propagated by opening voltage-gated Na+ channels, neutralizing the positive charge inside the neuron and starting a cycle, causing more gates to open and further depolarizing the neuron until an equilibrium potential for Na+. At this point K+ channels open, allowing it to flow out of the neuron shifting the membrane potential slightly below the resting potential. It being more negative causes hyperpolarization and K+ channels close, allowing the membrane potential to get back to its resting state. This whole process allows the AP amplitude to remain constant.
3. Refractory period: hyperpolarization period does not allow Na+ channels to open. This limits the amount of AP that a neuron can generate in a certain window of time. Also, this ensures that the flow can only be propagated in one direction, since that with this 'reload time' a current cannot open the gates that generated it.
4. All-or-none nature: APs must be considered as binary signals: the strength of the input does not result in stronger responses by the neurons.

2. Decisions can be reached using different strategies. Sometimes, they involve careful consideration of the expected outcome of our behaviour. Other times, they are generated more automatically, if a particular response has been repeatedly successful in the past. Discuss the characteristics of each strategy and how one can uncover which strategy was used for a given decision.

ANS: Goal-directed actions can be formalized using a model-based system. In this case actions would be selected using a model to predict the consequences of possible courses of action in terms of future states and the reward signals expected to arise from those states. If the environment changes the agent can simply update the system without modifying its structure.

On the other hand, habitual actions can be modelled without using a chain of actions, but using some sort of cache system in which every decision can lead to a certain value, associated with some kind of consequence. All the state-action values experienced over time are stored. Whenever the environment changes, the agent must experience the new outcomes and learn from them.

HOW TO UNCOVER THE STRATEGY USED FOR A GIVEN DECISION?

3. Discuss how associative learning is driven by surprise and prediction errors.

ANS: Associative learning is fundamentally driven by the concepts of surprise and prediction errors. Error occurs when the outcome of a conditioning trial is different from that which is predicted by the conditioned stimuli that are present on the trial (i.e., when the US is surprising). These errors serve as

potent signals that prompt the organism to update its internal model of the world, thus facilitating learning.

In classical conditioning, a neutral stimulus becomes associated with an unconditioned stimulus through repeated pairings. Initially, the neutral stimulus doesn't predict the outcome, leading to significant prediction errors. However, as the pairing continues, these errors diminish as the organism learns the association between the stimuli. Computational models such as the Rescorla-Wagner Model provide formal frameworks to understand these learning processes. They quantify the strength of associations between stimuli and outcomes, considering prediction errors as crucial elements in adjusting expectations and behaviour.

4. Are the amygdala, hippocampus and ventromedial prefrontal cortex necessary for both the implicit (psychophysiological response) and the explicit (declarative response) expression of Pavlovian threat conditioning? Evaluate the evidence in favour of and against this statement.

ANS: the amygdala is located in the medial temporal lobe and is mainly responsible in determining what a stimulus is and what is to be done about it. It is also involved in attention, perception, value representation, decision making, learning and memory. Its function creates an implicit response to threats, by remembering and associating the conditioned stimulus to the unconditioned stimulus. The response can be physiological and behavioural like high hearth rate, freezing or hormone release.

Hippocampus is a part of the brain connected to the amygdala and is crucial for memory formation and declarative memory. It helps form memories of the context in which the pairing between conditioned and unconditioned stimulus occurred. This type of memory is accessible by the subject, allowing it to recall it in case of a new event and use the previously acquired knowledge to modulate the response to an event or environment, namely, to determine its hostility.

Lastly, the prefrontal cortex allows long-term planning and organizing, executive functions, decision making, motivation and value. It regulates conditioned responses between CS and US, for example once the conditioned stimulus is no longer paired with the unconditioned one. Together with the hippocampus it can modulate the response and the importance of a conditioned stimulus.

Patients without a part, or the whole, organs beforementioned are not able to create new memories, or to better say, they don’t remember about them.

5. Neural signalling, within and between neurons

ANS: within a neuron there are multiple types of signaling, each of them with a different signal. A neuron receives a signal in the input region and grades it over amplitude and duration. More than one input might be needed to produce an output signal by the neuron. The dedicated zone to this behaviour is the so-called trigger zone. It sums up the inputs signals and decides whether to produce an action potential, in particular if the inputs exceed the -55mV threshold. At this point any other input could only increase the frequency of the action potential, not its amplitude. The signal is then propagated trough the axon, surrounded by myeline to speed up and protect the communication, in the conductive region. The output signal could be chemical or electrical, depending on the synapses type. In the first case the frequency of action potentials is directly proportional to the neurotransmitter released, if electrical the signal is simply passed over to the next neuron.

Synapses can connect to the dendrites of the postsynaptic cell or directly to its body. Synapses can also connect two axons together to create inhibition or facilitation for the propagation of the signals. In the case of electrical synapses, the two neurons are actually connected through some pores making their cytoplasm continuous. Chemical synapses aren’t structurally connected. Electrical synapses are mostly used for fast transmission or for synchronous operation of groups of neurons.

The ability of chemical synapses to modulate the signal allows a more specific use for the transmissions, at the cost of some speed. This speed loss is due to the delay between an action potential in the presynaptic cell and the synaptic potential in the postsynaptic cell. When an action potential arrives, the membrane of the transmitting cell gets depolarized, allowing an inflow of Ca2+ from the postsynaptic cell. Calcium causes vesicles, containing the neurotransmitter, to bind with the membrane and release the transmitter that is then going to bind to the receptors of the next cell.

6. Evidence for the hypothesis that dopamine neurons encode reward prediction

ANS: the substantia nigra pars compacta allows the switch from direct and indirect pathway from the striatum to the thalamus, by releasing dopamine. This neurotransmitter enhances the direct pathway while inhibiting the indirect.

One of the functions of this part of the brain is to give importance to the difference between the expected outcome of a certain action and the actual outcome and, in particular, the reward associated with it. It is, in facts, the error between the actual reward and the predicted one to produce dopamine. This neurotransmitter is fundamental in classical conditioning allowing the agent to give more importance to event that were misinterpreted. For example, whenever an unconditioned stimulus is way better than expected, the positive error might be large, producing an increased dopamine level. The underlying mechanism to enforce the connections between stimulus is the dopamine's ability to strengthen the long-term potentiation and depression of the synapses.

Altogether, this neurotransmitter leads to increasing attention to stimulus, in particular to previously experienced one, where the agent conducted a misleading prediction about the associated reward. Learning is the result of changes in the strength of synaptic interactions among neurons in neural networks. This has been proven with experiments on aplysia californica, where conditioning led to a larger withdrawal response to a single stimulus. This was done by pairing that stimulus with another one, leading to strengthen synapses causing a bigger reaction. → Hebbian plasticity: neural connections can be modified by experience and learning.

7. Neural and functional description of V1 (PART 2)

ANS:

8. Explain about contiguity and contingency and the experiments

ANS: let's start by giving some definitions:

- Contiguity is the closeness in time between stimulus/behaviour and outcome. Stimuli that are close to one another in time become associated. As we will see this is not sufficient for learning.
- Contingency is, on the other hand, the causal relationship between stimulus/behaviour and outcome. Whenever one stimulus depends on the other, they will become associated.

The most obvious way to associate a stimulus to a response is with contiguity: if immediately after something happened the agent experiences a reward or a fearful stimulus, then the two elements could be linked. The temporal vicinity of two events is not enough to be able to identify a connection. If for example there is a light switching from on to off repeatedly, and some food is given immediately after the light switches on but only once every four switches on, no strong connection will be made. In fact, contiguity by itself is not enough for learning, but what we truly need is contingency, in other words the fact that the conditioned stimulus gives information about the arrival of the unconditioned stimulus.

Experimenting with rats, it has been observed that in a situation in which there were some combinations of bell and shock. The role of the bell was to inform the rat that a shock was likely to occur, but it could also arrive without prior warnings. The rats did not develop a fearful stimulus over the bell, since that there was no difference in the occurrence of the shock. For another group of rats, the odds for a shock without warning was decreased, therefore the likelihood of a shock after a bell was higher compared to no bell. This environment led the rats to fear the bell.

9. Explain about goal directed and habitual behaviour (SEE Q.2)

   ANS:

10. Neural bases of visual motion (PART 2 I GUESS)

    ANS: