Please find below answers to learning diary questions, if any follow-up questions, please don't hesitate to ask via email iiro.jaaskelainen@aalto.fi ☺ Thanks once again for all the input, feedback and very good questions. On next sessions based on the feedback, I will keep to slightly larger breakout rooms (since some participants are not active some groups were limited to 1 or 2 persons when the rooms were smaller) and will try to have them 2-3 times each session, based on your feedback. Lets also have genuine breaks in addition to breakout rooms, and based on feedback I will try to come up with tasks/questions as starting points for discussion in the breakout rooms. I wish to thank for all the feedback as that really helps making the course better ☺

1. What is the relationship between attention and memory? Obviously you have to be focused when learning new things, but then a lot of the times I hear people say they don't remember any details of some of the most important events of their lives (weddings, baby's birth etc.)

Attending to-be-learned materials facilitates their consolidation during sleep. Sometimes emotionally traumatic events (paradoxically, also positive life events can be stressful, even to the extent of being traumatic) can cause memory loss of details.

2. How does brain decide whether a new information is important to remember?

Attention to the information that one wants to learn is one key mechanism, perhaps via acetylcholinergic influence. Significant events engage attention in a bottom-up manner, and we can voluntarily focus our attention.

3. In the end of the lecture there was some talk about the relationship of sleep and memory. Sleep spindles in stage 2 sleep seem to correlate with memory, learning and intelligence. Is it possible to stimulate more sleep spindles in the brain, and could this be a treatment for e.g. children with learning disturbances? (If this is the case it would be kind of a new ethical problem whether it is okay for rich people to get more intelligent due to these treatments)

Yes, there are such findings, via transcranial electrical current stimulation at slow-wave frequency there was enhancement of memory. The slow waves, sleep spindles are coupled. I assume that at least in theory it would be possible to non-invasively stimulate sleep spindles, though it is not straightforward. I agree, ethical considerations are very important in neuroscience and commercial applications thereof. One area where this is highly relevant is the marketing where results from learning by conditioning are readily utilized to get people to buy. Certainly also accessibility of medical care to rich vs. poor is another example.

4. Are there no other methods of learning out of the classical and operant human learning methods?

Yes, definitely, conditioning is only one route to learning. What we often think as the main mechanism of memorization is attentive memorization of e.g. significant details of episodic life events, as well as when one simply recalls events, thinks about them, resulting in new storage of those memories, in altered fashion.

5. What are sleep spindles exactly, why do they happen?

They are specific instances of brain's electrical activity recordable with EEG and intracranial EEG. There is some recent research indicating coupling of hippocampal ripples, slow waves, and sleep spindles, more on this in the beginning of next lecture.

6. Why do nightmares exist? Aren't they basically our own memory working against us? Why would our memory work against us when it is supposed to make our brain more efficient by removing junk and filing important stuff during sleep?

This is a topic where do not have definite answers, thus what I write in the following is educated guess. Nightmares are probably due to the brain going through emotionally adverse memory materials during sleep. Typically these materials are from the preceding day, but certainly in case of traumas, the past is present and coloring the previous day. In general, sleep and nightmares are then mechanisms that help alleviate, solve, the effects of adverse emotional life events on us.

7. Why is it often hard to control thoughts? For example, when going to bed, many cannot mute the running thoughts that are often stressful. I find those are most often about stressful deadlines or embarrassing moments from years ago.

When dealing with emotionally traumatic materials, it helps to repeat and "relive" via memories. Sometimes this self-healing mechanism can however lead into development of post-traumatic stress.

8. Why are there differences on how people remember their dreams? For example, I often remember my adventure movie like dreams, and I am able to describe whole stories of them, although not all of the dream elements make sense after waking up (sudden change of scene etc.). I remember the plots and tons of little details and visual appearances. To me, it sometimes sounds weird when comparing to other people's few memories of their dreams.

As we wake up, if we wake up in a sleep stage wherein memories occur, we can for a moment's time capture what we dreamed about just before. So this depends on both the timing of waking up relative to the dreaming-sleep-stages (mostly REM) and how we pay attention and recall dreams after waking up. I have an incidental observation on this: years ago I was in a MRI scanner where the experimental sequence had been built so that the scanner took images once every 10 seconds. The sound is 135 dB, so it is very difficult to sleep through, yet I had time to fall asleep, dream about being still awake, followed by multiple adventures, and then I woke up to the next noise burst of the scanner with only 10 seconds in between the noise bursts. So it

might be that time in dream has little to do with time in real life, rather the brain is producing associations (and create funny storylines, events) in parallel and as we wake up the brain interprets what is there currently in the neural circuits as narrated dreams (with weird turns) . But I have not empirical evidence to back this up, just introspection.

9. What is imagination? Does reading to a child affect the way their imagination develops?

Imagination from the perspective of cognitive neuroscience very much relates to the theories of associative brain, in which via interactions between midline default mode structures and hippocampus, the brain constantly generates at rest scenarios of possible future events ("daydreaming"). Certainly, reading improves the ability of a child to imagine.

10. What exactly happens in my brain when I read the chapter 7 in the book? Why do I learn better if I write notes from the book instead of just reading? As far as I understood, learning is basically the strengthening of synapses. So in theory, would it be possible to remove memories by blocking synapses?

As one reads chapter 7 of the book, a number of things of course happens, but maybe the most essential is how long-term memory schemas get refined and/or new ones are created as the result of learning. These schemata indeed is based on long-term changes in synaptic strength, distributed across the brain. There is evidence indicating that sleep helps consolidate these. One indeed learns better when one uses multiple modalities such as writing down some notes in addition to reading and listening. One possible reason for this is that one has to semantically process what one read or listened to as one writes down in a summarizing manner. The same holds for writing learning diaries ☺ There are ways to block formation of permanent (long term) changes in synaptic weights, for example, a strong electric shock results in retrograde amnesia, i.e., those memories that did not yet get "hardwired" as synaptic strength changes.

11. The different parts of the working memory remain somewhat unclear, more precisely how the arrow mappings in slide number 32 work together to form the working memory.

In Baddeley's working memory model, the central executive manipulates information in the auditory and visual sensory memory stores that also get information from the senses. The central executive also draws information from long-term memory to mix with sensory memory and stores information to long-term memory. This working memory model differs from short-term memory model mainly in that the emphasis is on active manipulation of information rather than passive retention of some of the information that has entered sensory memory stores.

12. I didn't quite grasp the underlying mechanisms behind event-segmentation. The boundaries in the cortex somewhat makes sense to me but the role of hippocampus in this process was not quite clear to me. What does the y-axel (FIR) in the graphs stand for? And why is higher "FIR" important in distinguishing a salient (or important) memory?

It is assumed that the hippocampus accumulates-retains information about the ongoing event and at the time of event boundary the hippocampus replays the information of the event quickly thus starting the process of memory consolidation into long(er) term memory – and then starts to accumulate-retain information from the new event that started. The other cortical areas likely are responsible for updating/holding the schemata relevant for the new/ongoing event. FIR stands for finite impulse response, this is professional jargon, a type of event-related fMRI data analysis method that does not require a priori assumptions (i.e., any model) about the shape of the hemodynamic response.

13. I would like to ask about presenting the forgetting rate as a function of time. Is this representation an likelyhood-averaged model of different subjects? The forgetting rate must be a multivariate equation in which time is only one of the several variables: age, 1 hormone levels, previous experience and so on? What would this analytical function look like if averaged and the time would be the only variable? (Also if there is a more accurate non-averaged model please show this too)

This finding presented in the course book is from older literature and yes it is true that these findings are average results across subjects with differences between them. The original study (most likely, if I recall correctly) was conducted in young healthy college students and then there are a multitude of studies that have investigated the influence of variables such as age, level of education, and cultural background. Here two examples from this literature as examples for more in-depth reading on this topic: https://doi.org/10.1016/0001-6918(85)90015-0 and https://doi.org/10.1016/0010-0285(78)90017-8

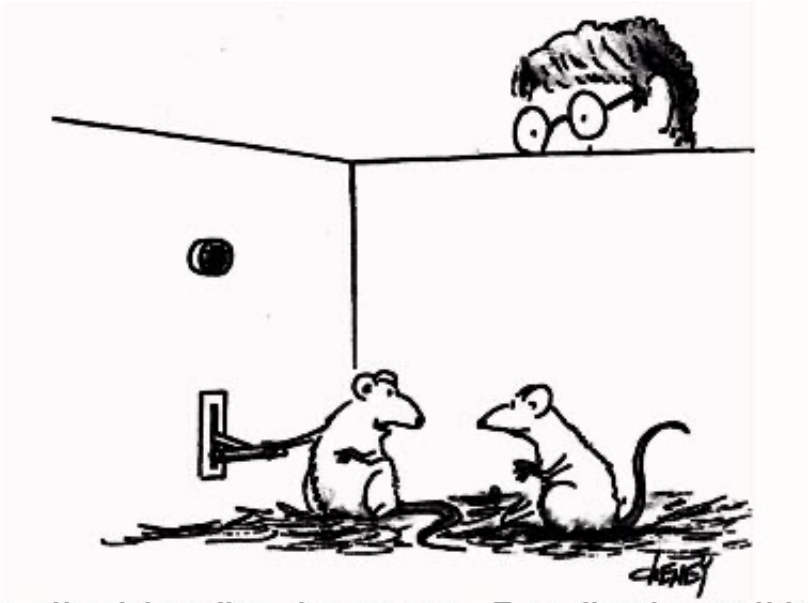
14. I have a question related to the video about the man without short memory. Is there any way to treat or alleviate a situation like this?

I tried to look for information on whether stem cell therapies (that can be used to treat Parkinson's disease via restoring dopaminergic cells to substantia nigra) have been tried out in these patients, or whether the adult neurogenesis taking place in hippocampus could be pharmacologically stimulated in these patients, but found no evidence for either. As far as I know the only treatment is managing the condition of the patient, for example, AI based electronic aids could help the patient (e.g., AI reminding and instructing the patient).

15. What kind of system controls the ethics of say, conditioning monkeys to press numbers in order for food? Or is there just one system for all ethics related issues for all research? Lastly on the topic of conditioning, I wonder if Pavlov became conditioned to think about feeding his dogs any time he heard a bell ring?

Research ethics are guided by national level legislation of different sorts, for example, GDPR has to be taken into account in EU when carrying out human research that has potentially identifiable information on subjects. Legislation on research ethics on animals is in general more strictly defined than research ethics on human volunteers (since volunteers are there for their own free will) but overall there should not be harm caused to subjects and some research that

would have been ok earlier is not ok today (for example studies on obedience to authority by Milgram in the 1960s as detailed here: https://en.wikipedia.org/wiki/Milgram_experiment would not receive green light from research ethical committees of today). While I do not know the details as well, outside of the scope of scientific research, there are guidelines and legislations for ethics in marketing, and the Finnish governmental non-profit gambling monopoly Veikkaus designs their games in such a way that they are not maximally addicting, due to ethical reasons. The last question brought to my mind the joke in this cartoon below ☺



16. What sleep actually does that causes improvements in memory?

Cleaning out of ”irrelevant” memory materials (like visual details of the corridor that one walks every day along to lunch café, unless there were some change to them) is one of the most important mechanisms. Sleep also has been shown to take separate memory materials and allow for new insights, seeing how they connect together. It is also a commonplace observation that after good night sleep, things that seemed puzzling the previous evening suddenly are clear. There are also emerging body of research findings indicating that during sleep the lymphatic system cleans the brain from waste-chemicals and this way good sleep is also important for brain health and that way via long run for memory too.

17. What benefits does event segmentation give to the brain?

One way to define an event is “whether the schemata concurrently in use that allow efficient operation in situation-context are still valid, or do we need to activate some other schemata”. For example, when we enter a restaurant, we know (based on schemata then activated) that we need to wait to get seated (if there is such a sign, we know to look for the sign) and that the waiter / waitress will soon come after sitting down and we will get a menu to browse and select

foods from. However, if one's supervisor suddenly calls, these restaurant schemata no longer help but would more interfere as we need to orient to work matters for the duration of the call. So thanks to event-segmentation, we can focus and have relevant schemata given context and situation and hippocampus together with cortex will quickly handle "wrapping up" and storage of what was going on until the event boundary. Perhaps of interest, hippocampal damaged patients sometimes can hold a conversation quite normally unless they are interrupted by someone or something. Once their event ends that event does not get stored, due to the hippocampus damage, and so once they get back to the conversation, they have no recollection of who it is they were talking with or that they had had a conversion a moment before. Such observations illuminate the role of hippocampus in event-segmentation.

18. How exactly are memories recalled?

It is believed that brain activity hitting distributed set of synapses across the cortex that have been modified due to learning or episodic memory gives rise to recollection. The role of hippocampus is lesser in recall than encoding, though not non-existent. Different types of recollections activate different cortical areas. For example autobiographical recall seems to depend on midline default mode structures (VMPFC, precuneous) , i.e., the same structures that run associations according to theory of associative brain by Moshe Bar that was briefly discussed during the lecture.

19. Can confabulation patients be treated or somehow taught to evaluate the real memories better?

Confabulation results from prefrontal damage and loss of insight is more general a problem than specifically limited to memory recall. One way to rehabilitate these functions is to give external feedback signals, like pointing out to the patient that something is not wise or appropriate behavior (as I will tell in 2 weeks, these patients often suffer from lack of impulse control) or that memories they produce are not accurate or true. This is a slow process and not easy, but rehabilitation is always possible over time. Here perhaps some electronic means such as some game-play that has memory checks might be helpful as means for rehabilitation. Naturally, one challenge is that often the listener has no way of verifying accurate of recollections, so catching this problem is best achieved with settings where the patient is for example told some narrative and then after a while asked to recollect the narrative. Gross alternation of the story then happens in patients with confabulation.

20. Does sensory memory "work" also for other senses? And does sensory memory actually play any (significant) part in learning or is there any connections to the people saying that they learn best by seeing/hearing/doing - or does that actually exists?

There is sensory memory for somatosensory modality, though it is less studied than visual and auditory. The operating principle most probably is the same. We do know that transfer of materials from sensory memory to long term memory is possible, based on behavioral findings. About the learning best via seeing/hearing/doing, this matches personal experiences of many, I

would say the best learning results are obtained when one processes the input somehow semantically, for example via brain-storming type of learning diaries.

21. What does the concept of eidetic memory or "valokuvamuisti" mean physically and practically? Are there other types of special memories such as eidetic memory? How does sensory memory differ from short-term memory? How long does a memory/knowledge stay in the "long term" memory? Can it stay there forever?

There is research on eidetic memory, some findings challenge the infallible accuracy - perception of such individuals have about their recollections, but overall I think there are differences in that such individuals do not so much base their perception and memories on categories and wholes but rather concentrate on details. Persons with autism spectrum features sometimes have very detailed memories as their interests are often particular and focused. Sensory memory is less abstract, more about retaining "raw" sensory information and of higher capacity shorter duration than short-term memory that means the retention of 7 +/- 2 "items" that are fairly abstract. For example, NGO for someone who knows it refers to non-governmental organization is 1 unit in short-term memory, for someone who does not know this, it is 3 units. Memories can in principle stay in long-term memory throughout life. This does not mean all memories would be retained for this long a duration. There is a debate whether inability to recall is due to interference by overlapping memories, or due to genuine forgetting, I would say both.

22. In the context of process memory, I was left wondering how we filter or choose from the prior information that we process. Also, in terms of long term memory, I wonder if lack of sleep can be correlated to a decrease in hippocampal volume. Overall in terms of sleep I guess the overall question for me is, after seeing all the positive effects of sleep, what are the drawbacks if sufficient sleep is not had?

It is an open question how we choose from all possible memories the concurrently active ones. One mechanism for this is provided by the quick associative processes served by midline structures of the default mode network together with parahippocampal gyrus. Another relevant aspect are the top-down schemata that are active and guide perception / filtering via top-down modulation of e.g. sensory cortical areas. One possible model here is that bottom-up (filtered) assemblies interact with the top-down representations in a dynamic manner and if there is a mismatch between the filtered (expected) and input, there is change in top-down representations. Indeed lack of sleep results in increased stress that reduces hippocampal volume, hinders neurogenesis in hippocampus and results in inability to concentrate, irritability, lack of cognitive flexibility, stress and poor memory. This process if prolonged can result in clinical depression and in susceptible individuals in psychosis.

23. Do you think that only way to achieve truly intelligent computer is to mimic the structure of human brains? Meaning that in future advancements in neuroscience and AI will go hand in hand.

This is a very interesting philosophical question, the answer depends on how one defines intelligence. AI has benefitted from many insights from neuroscience, for example layered structure of deep networks taught to process pictorial materials seem to mimic the layered structure (hierarchy) of the human visual system. Parallel processing (instead of serial single-CPU based processing as in early computers) maybe has been influenced by how the brain processes information in parallel. Yet many AI solutions have not been copied from or influenced by the brain. Something which is very interesting are new artificial brains, neuronal populations /mass grown from stem cells. Whether such artificial biological brains can learn and serve some purposes remains to be seen. Overall, as we know more about the brain, ideas flow more easily to AI development.

24. What is the difference between the memory concept and learning?

Learning (having learned something) either procedural or semantic refers to long-term memory (and skills) changes, probably via changes in synaptic connectivity. Naturally the concepts of learning and memory greatly overlap, but there are differences too as not all that enters say sensory memory results in learning. It is good to note procedural learning is very different, and more depends on basal ganglia, motor and premotor areas and cerebellum, for example, hippocampus-damaged patients can learn new skills even as they do not recall having ever practiced.

25. Are the temporal receptive windows and the phonetic coding different for a Finn who is used to long convoluted words? What effect does native language, in general, have on memory, especially since the way one talks about the future or time overall can differ highly between them?

In one study, slow vs. fast speakers were compared and their effects on temporal receptive windows of listeners. It was observed that the windows elongate and shrink, it is more the chunking of meanings that is relevant -- -this was the concept approaches that of event-segmentation and I see event-segmentation as the same as the longest of temporal receptive windows. On the other hand, there are findings indicating that German speakers have longer short-term memories than e.g. English speakers, since in German language one has to wait until the end of sentence to comprehend what was said, for example “Der Student hat ein interessante Vorlesung über Neurowissenschaften **nicht** besucht.” Where the “nicht” makes the difference whether the student attended the lecture or not and verb is, typical to German, last in sentence. (I apologize at the same time that my German is rather limited and even this simple sentence probably has some error that I cannot detect)

26. I also found it quite interesting to learn how important sleep is and what eeg recordings during sleep can reveal. I thereby wanderers if it is possible to predict learning outcomes based on sleep? Does that mean I should listen to this lecture before bedtime instead of Thursday afternoon?

It is possible indeed to predict learning outcomes based on sleep. How to time learning with respect to sleep is more tricky. Overall, something learned just before sleep gets best consolidated, on the other hand, often at the end of the day one's attentiveness is not in best shape, which impacts adversely upon marking the learning material as significant for the brain/sleep. Maybe the best advise (if one can) is to time the learning to time of day that works best for oneself (most alert, fresh, some are that in the morning, some in the evening) and then nap right after learning ☺

27. Given that there is a heightened obesity level, as lately reported by yle, should some advertisements for highly unhealthy foods and snacks be restricted, especially in the case of children-focused Tv shows? In Sweden all ads targeted at children under 12 are already forbidden, should other countries follow through?

This is a highly ethical-societal question: from the point of view of society, restrictions do make sense to the extent that individuals of the society agree with the restrictions (e.g., as a case example, of failed restrictions, prohibition of alcohol). Limiting advertising to groups who cannot decide for themselves, such as young children or persons suffering from early dementias would of course be ethical. On the other hand, there is strong tendency towards freedom of choice by individuals that goes with responsibility of individuals, so these decisions are very much political in nature.

28. For me, it turns out that the neural mechanism of memory is discovered based on the clinical cases, where some type of memory was dysfunctional, for example, anterograde amnesia is a result of hippocampus not functioning properly (or even removed). And I was wondering if there are other methods to study the neural functioning of memory mechanisms.

Certainly, neuroimaging methods can be used to investigate where and how in the brain memories are formed, how recall functions. Behavioral methods have really paved the way very much for understanding of human memory, and new neurostimulation methods allow for example temporary "lesions" via inactivating some areas of the brain and testing for effects on human memory.

29. How do the findings of Ben-Yakov, Henson in the Journal of Neuroscience (2018) depicted in the graph relate to event segmentation?

The graph shows hippocampal activity at the time of event-boundary, ie.., when one event stops and another begins. This activity varied in strength as a function of how salient the event-boundary was. The finding is important since it clearly indicates involvement of hippocampus in event-segmentation.

30. Is it possible that hemispatial neglect diminishes over time when patients consciously decide to widen their gaze of view a bit to the neglected side? Successively, of course, but does conscious and consistent training already improve their condition?

Yes, over time, when they are pointed out that they do not notice what is on the left side, they learn to orient that way, to compensate for their loss. Feedback is on this most important.

31. You have shown images when you were talking about different sounds and I don't really understand what it represents.

This probably refers to spectotemporal ripple sounds, the way to read these is that the y-axis represents sound frequency, the x-axis time, and the color code amplitude. In the lecture I played each sound that corresponds to these examples. These sounds then stimulate the neurons, and depending on which aspects of the sounds the neuron responds to, one can calculate the spectro-temporal receptive field of the neuron. For example, a neuron could respond to ascending sound of certain duration in a specific frequency band.

32. I don't really know what is represented in the graphs named "prefrontal ISC esp. at low frequencies"

This meant that inter-subject correlation of brain activity during watching of movies was seen mostly in low frequencies, i.e., slower fluctuations of brain activity were in sync across subjects in these areas, but not faster ones. This was hypothesized to be due to these regions tracking aspects of the movie where things evolve slowly such as plot of the movie.

33. You already have talk about that but I don't really understand what is the adaptation

Adaptation basically means that when a stimulus arrives that partially hits the receptive field of the neuron, the neuron gets initially excited, but then falls silent for a period of time. This falling silent for a period of time is due to surround inhibition and one term to refer to this is adaptation. Adaptation in the neurosciences and psychology can have some other meanings too, which is important to keep in mind. For example, adaptation to a new school (psychology) and sensory adaptation (for example the human visual system adapting when entering from bright sunlight to a dark room and vice versa).