Dear students – please find below answers to the very good questions you posed via Mycourses regarding the 27th of January lecture. Some of you provided feedback that the combination of breakout rooms with new types of tasks and real breaks was very good, so this is something we will continue with. Thanks for the helpful feedback ☺

Q1: Is the word map in the brain the same for the same word in languages other than one's native language?

There is evidence indicating that the semantic representations indeed match closely irrespective of language, this has been studied in bilingual individuals. Naturally, fine semantics do differ, for example, the word "love" has quite different meanings and uses in the United States from the word "rakkaus" in Finnish. Love in US is used quite liberally to express liking, in addition to serious love, whereas in Finnish the use is more restricted. As another example, the word coffee probably has much more associations and fine semantics in a coffee-culture country than in Finland. Differences such as these would naturally reflect on differences in the semantic maps. Also, it is good to realize that the subjects in the Nature 2016 study were few in number and I think mostly if not all lab members, which might have contributed to higher degree of similarity.

Q2: Also it would be interesting to know if there are some kind of semantics behind the functions of autonomic nervous system, like breathing. We can be mindful of our breathing if we want to, but also we don't have to, we'd still be breathing. But is there always some kind of thought of breathing and how intense it should be in the subconsciousness.

While breathing works very automatically and does not require conscious effort, we can become conscious of it and modulate it at will. I think the question is very good in that we can breathe heavily due to a variety of reasons and as we are in the border between subconscious and conscious, the breathing can easily contribute to emotional interpretation of situations. This means that heavier breathing due to for example mild case of covid can result in differential interpretation of emotional reactions if one is not aware of the disease. Just to give one example. More on emotions and this type of phenomenon in the latter half of the lecture today.

Q3: -The language center of the brain is frequently on the other side of the brain in left-handed people compared to those who are right-handed. Does handedness correlate with other broad differences in the general functional structure of the brain? -In the mapping of words to cortical regions that respond to those words, do the responses often come from regions with functionality related to the subject of the word? For example, do color related words generally trigger the visual cortex, and movement-related words the motor cortex, and the like?

Yes, handedness influences more generally the functional neuroanatomy, for example, distribution of areas supporting visuospatial perception. Indeed, semantically/functionally

nearby words are nearby in cortical space. This may be relevant for priming effects. For example, seeing a cat primes one's brain for information relevant to cats, such as how they behave.

Q4: - If we had an artificial sense, where would it be processed in the brain? Normally we have for example visual and auditory cortices where visual and auditory information is processed. But if we add a new sense, where will that be processed? If a person becomes blind, the visual cortex is freed to do other processing, but in the case when none of the senses or other brain functions become free, what parts of the brain learn to process this new kind of input? - Kind of related, but what happens when we add a new, artificial limb to a person who is not missing any limbs? For instance, a third hand. Is it possible for the motor cortex (and the rest of the brain) to learn to use this artificial limb when it doesn't replace any existing parts? - Regarding word semantic maps in the brain, is there a correlation between the semantic category of the word and the place it activates? For example, does words related to moving activate the motor cortex? Or do words related to music activate the auditory cortex? - How do semantic maps work across different languages? Do the words "car" and "auto" activate the same place in the semantic map? Or does each language have its own map in your brain?

Many so very good questions: the brain area that would start processing info from an artificial sense would depend on the route of input (e.g., if infrared info is presented via smart glasses, the info gets processed in the visual cortex) and also on what the info is being used for. For example, if infra-red information would turn out to be highly significant for interpretation of others' emotional states and social cognition, then the respective brain areas would process the new information. The same applies to third hand or some other extension. Words related to actions indeed activate the motor cortex etc. as anticipated in the question.

Q5: I could not really understand if there is a benefit in an evolutionary sense that brain plasticity worsens over time. The long-term plasticity versus plasticity, and how longterm plasticity can be achieved, is still a bit unclear.

We are a rather unique species in that we are born with capabilities to adjust to a wealth of different kinds of environments. Initially it makes sense to have a lot of plasticity to allow good adjustment. Once we have adjusted and nothing much changes in our daily lives (in the big picture) it makes sense for the brain to be less plastic.

Q6: This was not included into this lesson, but what I'd like to know is how the fact that some people constantly have an inner dialogue versus never having one, differ in terms of speech and other neural activity?

There are other daydreaming contents than social – this is one important point to make. Autistic individuals are not interested in social aspects, social signals are not prioritized by their brains and – as partial answer to this question—they exhibit differential default-mode network activity at rest as compared with neurotypical subjects. Contents of daydreaming also differ.

Q7: How does neuronal adaptation occur on the cellular level? • Is it possible to tamper with brain plasticity, e.g., with certain drugs? • What makes language such a specialized function, that the various language processing deficiencies cannot be corrected for?

There are multiple mechanisms for neuronal adaptation at the cellular level, but inhibitory inter-neurons are perhaps the most important. The article Kolb et al. mentioned in the last lecture listed a few candidates from stimulants to neural growth factors, mostly such that have worked out in animal studies. It is a very good review article, yet a bit dated, having been published in 2011.

Q8: Does stress or emotions affect plasticity?

Yes, prolonged stress is known to reduce hippocampal neurogenesis, adversely impacting learning and plasticity, and emotions naturally are a big factor in driving prolonged stress. It is good to note that both negative and positive (and not only negative) life changes produce stress response.

Q9: I found it surprising that schemes were located at the same spots in different brains. I was left wondering whether or not all these testees were from similar cultures and similar language groups? And would there be more separation between people from different backgrounds? All in all, is there any hypothesis on why some specific scheme is located in a specific area?

This is a very good question. As far as I have understood, the subjects were few and from very similar backgrounds (mostly lab members) and overall there is a bias in science conducted with volunteers towards young healthy university students and/or lab members. Cultural differences certainly influence the semantic maps, we even have some (still unpublished) findings on that even family cultural background (Russian minority and Finnish majority) of Finnish subjects can influence their fine semantics. Perhaps a good example of this is how the word “coffee” could be represented in the semantics in a lot more rich way for someone from a coffee culture (e.g., cappuccino is to enjoyed only on some specific time of the day in Italy) vs. someone from a non-coffee culture (e.g., Finland in the 1980s when the question that was asked about the type of coffee one wished to order in a restaurant was limited to “with or without milk, sugar?”) To answer the question of why a specific scheme is located in a specific area, I would say this is driven by where and how inputs tend to converge in the brain. For action words, it is natural that they are connected with somatosensory and motor cortices.

Q10: I would love to know more about the mechanisms behind stimulant induced plasticity. What do studies say about the mechanisms of drug induced plasticity?

This is a very good question. Looking at the literature, I find some leads, for example, stimulants seem to augment the process of up-regulation of AMPA receptors on cellular level, which could be a mechanism promoting plasticity (https://doi.org/10.1016/j.neuropharm.2004.07.006). There

are probably multiple different mechanisms behind this, not the least via modulation of attentional focus.

Q11: Are there any cases of motor cortex damage that affect the speech perception?

It has been shown that temporary disruption of motor cortex (with TMS) does adversely impact phonetic categorization. The current consensus seems to be that in specific instances, like perceiving speech in noise, and phonetic categorization tasks the motor and speech motor system play a role. Also, there could be altered aspects of cognition and perception, of especially action-word semantics, with motor deficits. The concept of embodied cognition is a very central one in this.

Q12: Neurogenesis rate in different cortical areas differ. Are these rates always ordered according to the use/importance of the area - e.g. is the neurogenesis rate in the visual cortex greater than the neurogenesis rate in the auditory cortex?

The greatest rates are observed in hippocampus, which parallels the role of this structure in plasticity and memory. As a generalization it could be said or speculated that there is higher neurogenesis in areas that are involved in memory and plasticity and less in areas where things remain more stable. For example, prefrontal cortex that "houses" personality seems to have less neurogenesis. Perhaps this relates to our personalities being relatively stable (even though psychological need to see oneself as a stable unchanging self over time also contributes to this).

Q13: In the video we watched, we were told that the same words can be found in multiple places, such as "top" being grouped with clothing, numbers and measurements, as well as buildings and places. This means that the words are not stored simply as the words themselves, but they are processed based on the meaning of the words, and then stored to the corresponding category. I wonder, does this categorization and organization happen in the brain as a whole, or could there be a part of the brain that does this and "sends and order" to the other parts to store and respond to certain words?

Here, I would speculate that are a few mechanisms would be relevant. One if what happens during sleep, the nesting of hippocampal ripples, thalamic sleep spindles and cortical slow wave up-states that result in modification of synaptic strengths. The semantics probably over time develop and are refined by this process. Ascending acetylcholinergic inputs to cortex from the Nucleus Basalis of Meynert seem to be also very relevant for learning, including probably learning of semantics. Lastly, anterior temporal lobe might be a hub that via connectivity across the rest of the cortex seems to play a key role in processing of semantics, probably also in learning of semantics.

Q14: How is plasticity measured? eg. the boosting effect of plasticity that drug has.

This is a very good question, often this is behaviorally assessed recovery of function, but this is subject to valid criticism. Many plastic processes fail to support recovery of function, yet the

ones that do support recovery are the clinically most meaningful, this is probably why they are favored.

Q15: Is it possible that other animals have a language of near similar richness as humans, but it is so much more different that we are not able to understand its existence?

Dolphins come to mind when reading this question, as well as elephants. We know that these species have high intelligence and complicated communication sounds. For example, for dolphins, see https://doi.org/10.1080/09524622.2019.1613265. This is still by and large an unexplored question. Speaking of high intelligence, some birds exhibit indices of high intelligence when specific tasks are used. Also in case of birds, there is the problem of failing to understand their cognition in order to assess it properly.

Q16: If the same semantic concepts can be in multiple locations in the brain, how are these multiple locations used together in language processing?

The brain is a parallel processing "machine" with distributed representations; there are lesion, stimulation and neuroimaging findings, touched upon in the lecture, pointing to the role of anterior temporal lobe in coordinating the retrieval of semantics across representations distributed across the cortex.

Q17: In the book I read that language processing and thereby reading happens mostly in the left hemisphere, and musical interpretations in the right hemisphere. But what about when one is reading musical notes? Does it resemble more the mechanisms regarding to reading, or the mechanisms that has to do with music?

Based on the research I managed to find, it seems reading musical notes and English both engage the left, language-dominant, hemisphere, in right-handed subjects.

Q18: I was wondering how the post-traumatic stress disorder can be treated in the perspective of plasticity?

PTSD treatments focus on partial re-activation of the trauma in safe conditions via which the memory materials become less stress-inducing. Drugs that would increase plasticity as well as those that alleviate the stress response (such as beta-blockers that deter sympathetic responses such as increased pulse), hold potential in facilitating such therapy work.

Q19: I started wondering few things: how does it affect to ones brain and ability to learn languages whether he/she learns one or two languages after birth? And does it exist that others learn easily different languages than others?

Yes, ability to learn languages differs across individuals. As a rule of thumb, the more languages one knows the easier it is to learn new ones, yet this also depends on how closely related the new language is to the previously learned ones. For example, learning Swedish is relatively

easier to learn for a German speaker than learning Finnish, since Swedish and German are very closely related languages and this is not the case for Finnish and German. There have been studies comparing brains of bilinguals and monolinguals, and it seems that the brains of bilinguals show significant differences to monolinguals, as a recent example see: https://doi.org/10.1017/S1366728918000883

Q20: It was surprising to me, that mind reading could be already possible using non-invasive neuroimaging techniques. I would be interesting to know, are these techniques used in e.g., when investigating crimes, or is it forbidden?

After September 11th, 2001, the US government spent significant amounts of research funding to further the development of the use of neuroimaging in lie detection. The use of "lie detectors", such as polygraphs where the autonomic nervous system gives stronger responses to crime-scene details than to non-crime scene details, in courts this is indeed an ethical issue. I believe the neuroimaging based lie detection paradigms are (mostly nowadays) based on differences in brain activity when fabricating a story and when speaking the truth. However, there are ways around this as well as the polygraph. Mind-reading at this point would not be reliable enough to be used for the purposes of crime investigation.

Q21: The extinction trials were also a interesting concept in this weeks lecture, and I wonder if such receptor blocking antagonists can occur naturally, or are they only present when administered externally?

Indeed endogenous antagonists have been discovered in the body, but I am not aware that there would be endogenous opioid antagonists.

Q22: the lecture slides stated that recovery from brain injuries often results from compensatory strategies in reaction to a disrupted nervous system for the most part. This sentence got me thinking about whether behavioral improvement is due to developing compensatory mechanisms or recovery. Or could these behavioral and neuroanatomical changes reciprocally correspond to each other?

This very much depends on the case, but overall, when there is a behavioral-level change, there is some change in the brain.

Q23: The book tells about the studies where has been found differences in the roles of speech played by left and right hemisphere. Is there some clear reason why someone can have left hemisphere dominant, and someone can have right one? Also, what is the connection between handedness and that?

In right-handed persons the left hemisphere is usually speech-dominant, in about half of left-handed persons, it is vice versa. It is not known why this is so, perhaps the use of dominant hand requires visuo-spatial-motor skills that then drives the development of those in the non-language dominant hemisphere.

Q24: Since it was mentioned on the lecture that "you become what you do", is there a lot of research about how big effect can meditation have on a person and brain plasticity?

There is no systematic research on this (as one looking across all medications) but certainly some medications can have a large impact on brain plasticity.

Q25: (During pandemic times) I wonder if the combination of wearing a mask and having foreign pronunciation make it difficult for others to understand what is being said?

Indeed this is so, since reading the lips and other parts of face helps interpret what is being said, especially when the auditory signal is less clear. Even I as a native speaker notice that in noisy environments I tend to instinctively lower the mask when trying to explain myself.

Q26: Is pure word deafness often associated with damage to the Wernicke area?

Yes, pure word deafness often results from damage to middle temporal gyrus, which according to modern (non-textbook) views is an integral part of the loci of Wernickes's area as described in the original reports in German by Dr. Wernicke.

Q27: Is the increasing use of technology (substituting former ways of handling situations, like using google maps instead of exploring or relying on intuition) responsible for plastic changes as well? In a way that, for instance, our abilities to generate cognitive maps diminish due to the availability of google maps.

This is a very interesting question. Certainly our brains adapt this way to the environment and external aids shape our abilities. For example, there is less emphasis on memorizing details as one can always check from the internet, and thus memory to details may suffer at the expense of understanding of wholes and skills of how to locate information in www. Some years ago, there were findings of larger hippocampal volumes in London cab drivers, apparently due to their need to navigate in the city without any electronic means. Such plastic changes would not be evident in the brains of cab drivers who used only navigator.

Q28: Another impressive topic related to that is technical innovation we talked about, which is supposed to help blind people translate sensory and auditory input to visual information. But I was wondering, if this can work for congenitally blind people as well or only for people with acquired blindness? Or does the cause for the blindness play a role for the ability to actually represent something visually?

It seems that these tools work for both congenitally and late-blind, though one can assume there would be qualitative differences in how this is experienced as in late-blind individuals there is previous experience of seeing things.

Q24: I know that there are some periods in which it is easier to learn a language for example. My question is: why is one period better than another?

This is a very good question. I think this is due to more complicated functions being built upon more elementary functions that need to develop first. For example, ability to see, hear, and move one's muscles are needed before one can start learning of speech. Certainly, blind persons also learn to speak, but there is evidence indicating that vision does play a role in learning to speak, as sounds and meanings become associated with speakers and intentions. This answers why there cannot be sensitive period for learning a language before learning some of the more basic perceptual-motor functions. The answer to why the sensitive period for language does not seem to stay open – I am inclined to believe that this is since we get along most often with the language(s) we know already. Language learning can happen in adults very impressively when one is placed (immersed) in an environment where his/her own language(s) are not being spoken, such as when moving to a foreign country. It is still far from easy, but also for children it takes months, even years to learn a language.