2-IKVa-956/18 - Cognitive phenomena

Syllabus for MEi:CogSci State Exams

Master programme in cognitive science
FMPI, Comenius University in Bratislava

Starting in January 2023, this document replaces all its previous versions, please disregard them.

Instructions for students

The state exam is a final exam in your MEi:CogSci study. Its purpose is **not** to make you learn **new factual knowledge**, but rather to make you think and gain an **integrative perspective on the material you have already learned in the courses** you took. You should be able to look at cognitive phenomena from different angles and see their mutual connections. That is why in this material we do not provide you with answers, just with questions you may expect at the exam (the list is not exhaustive, that means these are just examples of questions we may ask). If you do not remember the answer, try to think and generate it on the fly using your general knowledge of cognitive science as well as your common sense.
We provide a list of relevant courses for each cognitive phenomenon using the following acronyms:

IP = Introduction to Psychology (Marko)
CP = Cognitive Psychology (Marko)
ICS = Introduction to Cognitive Science (Takac)
CCN = Computational Cognitive Neuroscience (Benuskova, Malinovska)
MBR = Modern Methods in Brain Research (Cimrova)
ICI = Introduction to Computational Intelligence (Farkas)
STH = Science, Technology and Humanity (Takac, Gal)
IFM = Introduction to Philosophy of Mind (Toskovama)
GC = Grounded Cognition (Farkas)

Your notes or teacher's course materials may help you when preparing for the exam and thinking about the questions. Many topics are also covered in the book Friedenberg J. & Silverman G. (2012) Cognitive Science: Introduction to the study of Mind (2nd ed.), SAGE (marked in the list with the acronym FS). The questions combine different perspectives on the phenomenon - these are marked with **(P=psychological, N=neuroscience, C=computational, F=philosophical).** We also sometimes list relevant keywords to look for on the internet. That doesn't mean that you have to read and learn all the provided materials: they are there more for your reference, to direct your search and to help you create your answers.

Once again, our goal is not to test your ability to memorize encyclopedic facts or your short-term memory capacity :) but rather your ability to connect the dots and think in an interdisciplinary way.
During the exam you will randomly choose one of the cognitive phenomena below. You will have 30 min to prepare your answer. Then you will freely talk and answer additional questions from the exam committee. General questions related to any phenomenon can look like this:

- Describe the basic concepts related to the phenomenon X.
- If you were to design and conduct an empirical experiment to study X, how would you do it?
- What would a computational model of X look like? If you remember, present an existing model, if not, talk about a hypothetical one. Which paradigm does your modeling approach belong to?
- Talk about X from perspectives of relevant cognitive science disciplines (psychology, neuroscience, philosophy, AI) and their methods.
- Talk about the phenomenon X from the perspective of the cognitive paradigm Y (Y=classical cognitivism, connectionism, embodiment/grounded cognition, enactivism).
- Critically evaluate the model/approach. What are its strengths and weaknesses?

Examples of more specific questions for each phenomenon are below.

Syllabus / List of cognitive phenomena

1. Perception
2. Attention
3. Memory
4. Learning
5. Embodiment
6. Mental representations
7. Language
8. Emotions
9. Social cognition
10. Consciousness

Examples of questions

1. Perception

- How does human perception work? What is the role of bottom-up (templates, features, prototypes) and top-down (assumptions, context, expectations) mechanisms?
- Describe the structure of the brain's visual system (receptive fields of neurons in the retina, LGN, V1 and higher visual areas). What are the functional differences between the ventral ("What") vs dorsal ("Where/How") pathway in visual processing?
- How would perception work in a computational system, e.g. in a robot? What would the systems for visual, auditory, tactile and proprioceptive perception look like? Hypothesize their main components.
- How could an algorithm for computer vision look like and what types of representation could it process? If you do not know an existing model, hypothesize one.

Suggested reading:

- P: CP, FS-ch4
- N : MBR, FS-ch6
- C: CCN

2. Attention

- What are the main functions and components of attention? What is the difference between bottom-up (automatic) versus top-down (controlled) attention? What is saliency? What is vigilance? Using what paradigms and tasks can attentional functions be studied or tested?
- What is an oddball paradigm and how can it be used in experiments studying attention?
- What are the neural areas related to attention (Knudsen)?
- Imagine a computational system with a processing bottleneck (e.g. a visual object classifier that can classify only one object at a time). How could an attention mechanism help to effectively deploy the system's resources? Describe a general architecture of such a system (e.g. Itti and Koch's model, or if you do not remember it, a hypothetical one).

Suggested reading:

- P: CP, FS-ch4
- N: MBR, FS-ch6, "oddball paradigm"
- C: CCN, Itti and Koch's model of saliency-based visual attention

3. Memory

- Is memory a monolithic system? Explain different types of memory (e.g. declarative vs. procedural, semantic vs. episodic, short-term vs long-term). What is working memory (Baddeley, Cowan) and what are its main components? Define the main processes involved in memory formation and retrieval.
- Explain the methods for probing memory functions (e.g., terms free recall, cued recall, recognition). How can they be incorporated into empirical experiments?
- How are memories stored in the brain? What is the functional difference between hippocampal and cortical memory? What is the role of the hippocampus and the cortex during encoding, consolidation and retrieval of memories?
- How can memory be implemented in computational systems? Provide examples from different cognitive science paradigms: what do memories correspond to in symbolic systems vs. connectionist systems vs. dynamical systems and how they are stored and retrieved?

Suggested reading:

- P: CP, FS-ch4
- N: MBR, FS-ch6
- C: CCN

4. Learning

- Explain the difference between classical (Pavlov) & operant conditioning (Skinner).
- What is implicit/motor learning? How could learning (in the form of habituation/systematic desensitization) help with treatment of phobias?
- How is reward and punishment (e.g., fear acquisition) implemented in the brain?
- What are the biological principles of learning (synaptic plasticity - LTP/LTD)?
- Explain the differences between the main types of learning in computational systems: supervised learning, unsupervised learning, reinforcement learning, probabilistic (Bayesian) learning. Describe how you would design a computational system using each type of learning (or provide examples of existing algorithms / learning rules / computational architectures).
- How do these computational types of learning map to learning in psychological terminology (e.g. associative learning, classical & operant conditioning, learning with a tutor)?
- Think about learning from the point of view of different paradigms in cognitive science: what would learning look like in a classical cognitivist system vs. a connectionist / neural network system vs. an emergent/enactive/embodied system?

Suggested reading:

- P: CP, IP, FS-ch3
- N: FS-ch6
- C: CCN, ICI, FS-ch7

5. Embodiment

- What is embodiment? How is embodied / grounded cognition approach different from earlier paradigms in cognitive science, especially classical cognitivism? What are its philosophical implications?
- How does the embodiment manifest itself in perception, cognition and action?
- How would you design an empirical experiment providing evidence for embodied cognitive processing, e.g. in language domain? Provide an existing example, or generate a hypothetical one.
- Can you remember some brain areas reflecting the human body (e.g. the sensory and motor homunculus)?
- What are the implications of the embodied approach for computational cognitive modeling? How would embodied models of cognition differ from disembodied ones? Try to provide an example.
- How is the embodiment paradigm reflected in robotics and human-robot interaction (HRI)?

Suggested reading:

- F: ICS
- C: ICI, GC, FS-ch13
- P: GC, “embodied language processing”, “grounded cognition”
- N: “sensory and motor homunculus”

6. Mental representations

- What is knowledge? How is knowledge represented in the brain? Explain different types of mental representations (e.g. visual, words, propositions, schemas & scripts).
- Explain the difference between feature-based, prototype-based, and exemplar-based representation of semantic categories. How would a classification (e.g. determining that the currently perceived entity is a dog) work in these three different types of representation?
- What is the difference between modal and supramodal representation?
- Explain the formalism of semantic networks and how they can represent semantic knowledge. How would the process of free associations (e.g. school -> student -> vacations -> summer -> beach) arise in a semantic network and how is it related to activation spreading? What is priming and how can it be implemented in a semantic network?

Suggested reading:

- P: CP, FS-ch1,12,14
- N/CP
- C/FS-ch7

7. Language

- What are the properties of (natural) language? What is the difference between phonology, morphology, syntax, semantics and pragmatics?
- How does language production and comprehension work (Levelt's model)?
- Nature-nurture debate in language: language as an innate vs acquired system, language -specific module vs. general-purpose mechanisms. How would you argue for each side? Poverty of stimulus argument.
- What are the main brain areas involved in language processing? Is language lateralized in the brain? What can different types of language disorders (e.g. Broca's and Wernicke's aphasia) teach us about language processing? How are meanings (semantics of language) represented in the brain? Which experiments support the hypothesis that meanings are embodied (if you cannot remember an existing one, design a hypothetical one)?
- Which aspects of language can be modeled computationally and how? Provide examples of existing models or describe a hypothetical one. How could a symbolic model of a language differ from a connectionist one? What is a (statistical) distributional model of a language?

Suggested reading:

- P/CP
- N: CP, IP, MBR, FS-ch9
- C: CCN, FS-ch9, GC

8. Emotions

- What are emotions and what is their function?
- Describe some of the existing theories of emotions, e.g. universal basic emotions (Ekman), socially constructed emotions (Feldman-Barret), circumplex/arousal-valence model (Russell), Cannon-Bard theory, Schachter-Singer theory, Appraisal theories (Scherer).
- How would you design an experiment supporting the existence of cross-culturally universal basic emotions?
- How would you assess human emotions using electrophysiological measurements?
- Affective computing is a domain of creating AI systems able to recognize human emotions and react to them appropriately; what are the perceptual cues of human emotions and how would you design a system able to recognize them? What would be needed for an AI system to display its own (faked or real) "emotions"?

Suggested reading:

- P: IP, CP, FS-ch10
- N: MBR, FS-ch10
- C: STH, FS-ch10

9. Social cognition

- Method-wise, how would studying social cognition differ from studying individual cognition?
- What is the theory of mind (ToM) and what is it good for? How would deficits in the ToM influence social cognition? Can you remember any experiments/tests for the presence of the ToM (if not, try to design your own)?
- What is joint attention? What role does it play for social cognition?
- What is the mirror neuron system and what role does it play in social cognition? What are its neural correlates? How would you support the existence of a mirror neuron system using electrophysiological measurements?
- How would you model social-cognitive phenomena computationally? Provide an example of an existing or a hypothetical model. Explain the terms multi-agent systems, emergence, artificial life.

Suggested reading:

- C: ICS, FS-ch12,13
- N: MBR, FS-ch11, GC (lecture 3)
- P: FS-ch11ğ
- Social Cog Summary

10. Consciousness

- How would you define consciousness? If you remember, describe some of the current theories of consciousness (e.g. Higher-order theories, Integrated information theory, Global Neuronal Workspace, Predictive processing).
- What are the neural circuits related to conscious experience?
- Can there be / is there unconscious cognitive processing? Support your answer with evidence or (existing or hypothetical) experiments.
- What are the philosophical arguments for/against machine consciousness (e.g. Searle's Chinese room argument, philosophical zombie)? Can there be intelligence without consciousness? Justify your answer.

Suggested reading:

- P, N, C: Consciousness on Scholarpedia
- F: IFM, FS-ch2, Mindt & Montemayor (2020), "mind-body problem", "Chinese room argument"
- N: Dehaene (2017), FS-ch2
- C: CCN