

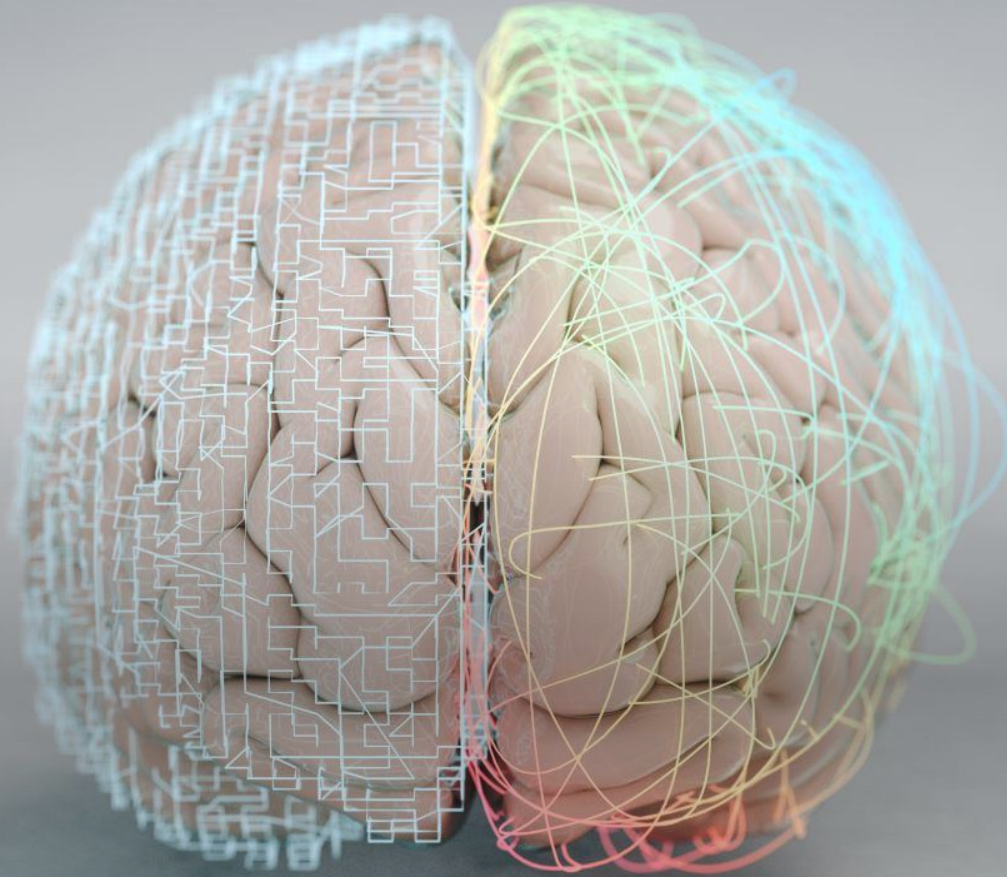
Neuroscience for Education

Neurodidactics

Brain & Learning

Mind – Brain – Education





Diversity & The Learning Brain

Brain Areas & Functions

BRAIN HIERARCHY

FRONTAL LOBE

- *Abstract Thinking
- *Problem Solving
- *Reasoning
- *Executive Functioning
- *Organizing
- *Motor Functions
- *Regulates Emotions
- *Expressive language

FUNCTIONS

- *Organizes thoughts on paper
- *Remembers facts from teacher
- *Starts and completes tasks
- *Tells stories

TEMPORAL LOBE

- *Speech
- *Auditory Processing
- *Hearing
- *Behavior
- *Emotions
- *Short-Term memory
- *Long-term memory

FUNCTIONS

- *Processes what the teacher teaches
- *Fear
- *Fight or Flight
- *Retains Facts

FRONTAL LOBE

TEMPORAL LOBE

PARIETAL LOBE

PARIETAL LOBE

- *Sensory Information

FUNCTIONS

- *Taste
- *Touch
- *Smell
- *Temperature

OCCIPITAL LOBE

OCCIPITAL LOBE

- *Visual System
- *Visual Information

FUNCTIONS

- *Processes words on a page
- *Knows shapes and sizes
- *Recognizes letters
- *Knows left from right

CEREBELLUM

CEREBELLUM

- *Balance
- *Coordination
- *Attention
- *Rhythm
- *Proprioception
- *Vestibular

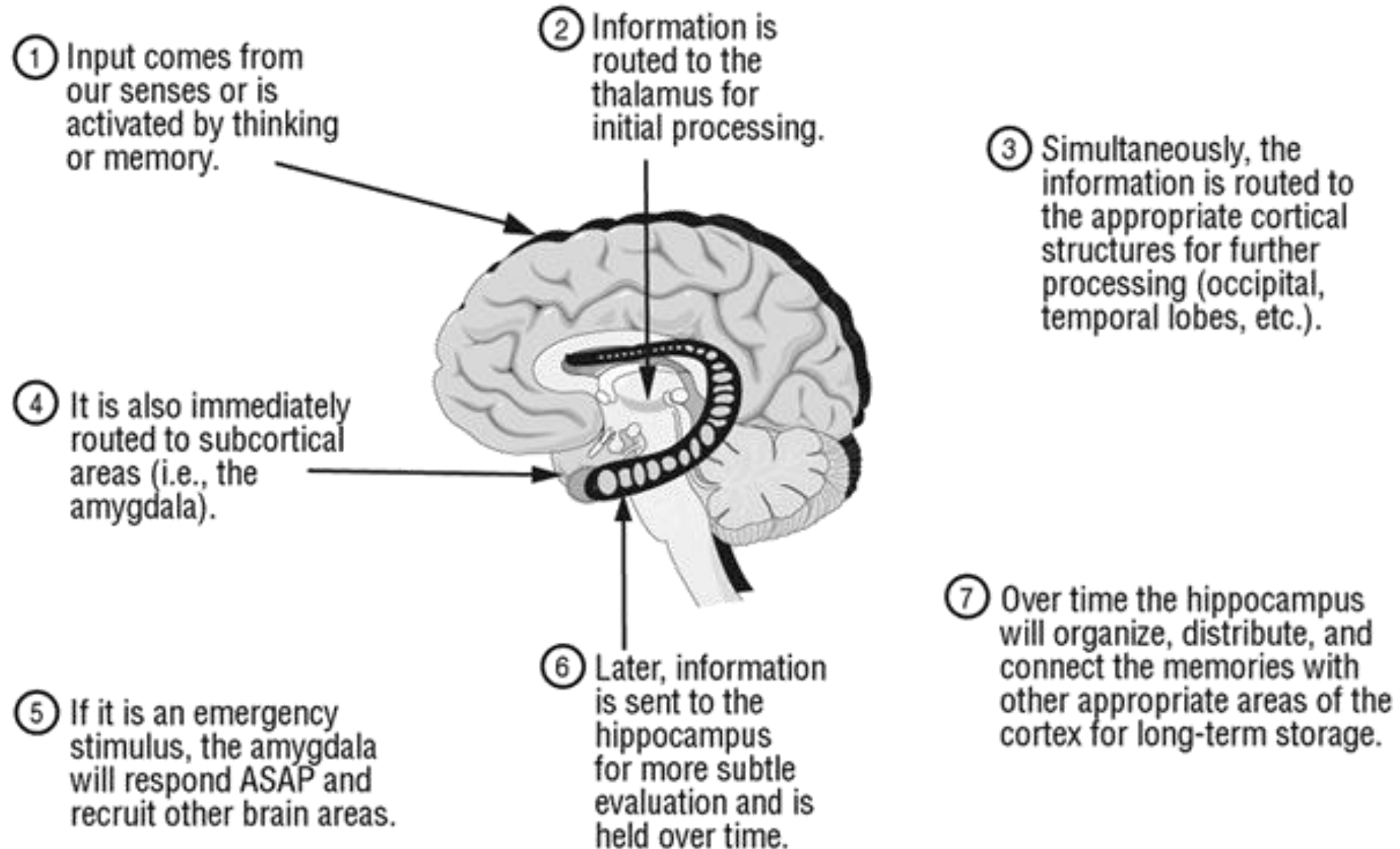
FUNCTIONS

- *Kick a ball
- *Throw a ball
- *Jump on one foot
- *Ride a bike

SPINAL CORD



The Learning Brain



Neurons and Synapses

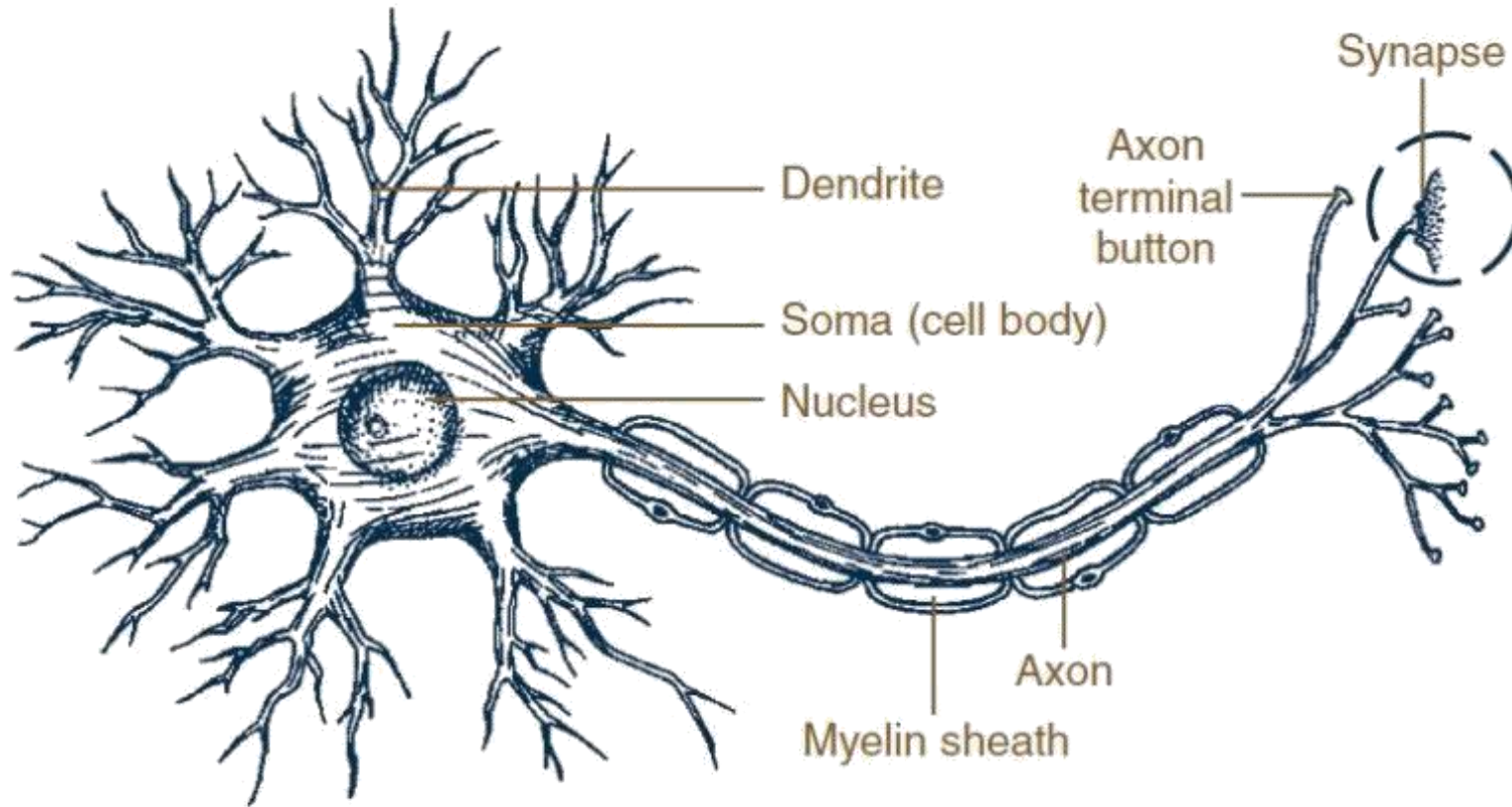


Figure 1.3 Neurons transmit signals along an axon and across the synapse (in dashed circle) to the dendrites of a neighboring cell. The myelin sheath protects the axon and increases the speed of transmission.

Sousa, David A. (2006). How the brain learns.

Neuroscience for Education

Factors influencing gender & individual differences

Genetic influences

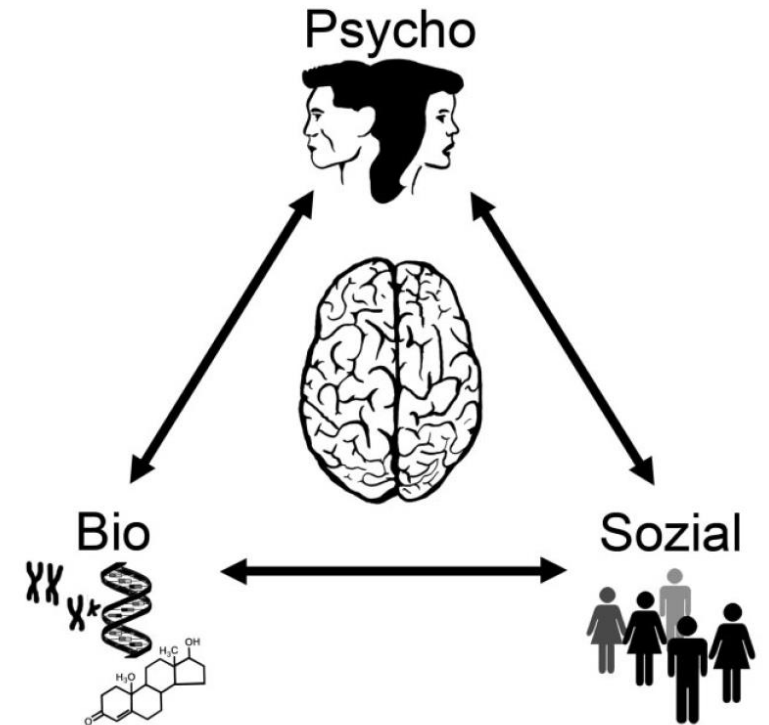
Hormonal influences

Maturation rates

Brain organization

Cognitive editing strategies

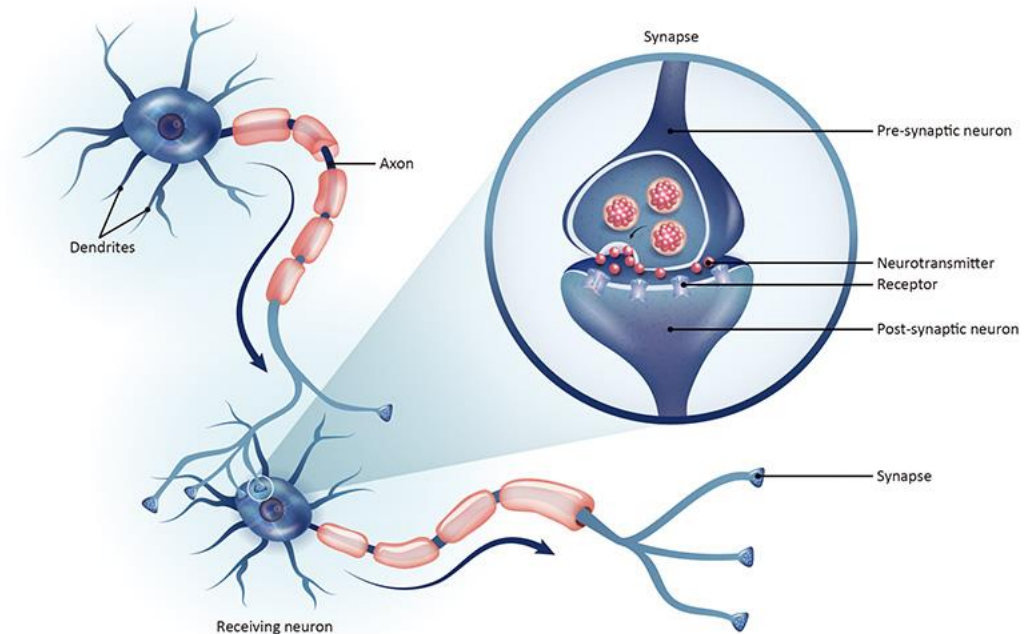
Environmental influences and learning experiences



Hormones & Neurotransmitters

Regulate motivation, interest, attention, learning capacity

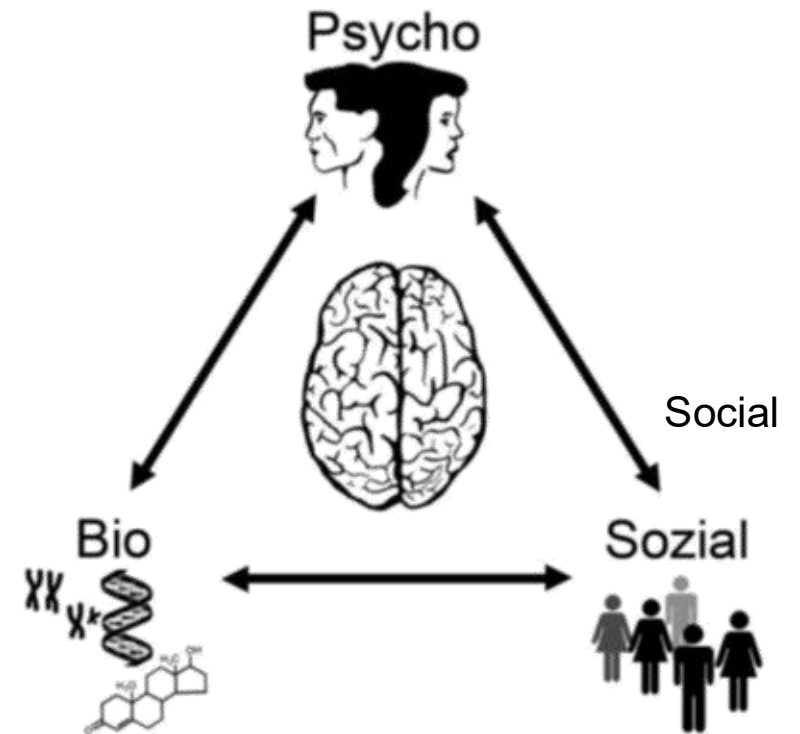
- Estrogens:
 - High level: verbal intelligence
 - Low level: spatial intelligence
- Testosterone:
 - Memory
- Serotonin:
 - “feel good” chemical
- Glutamate:
 - Concentration, memory
- Acetylcholine:
 - Fosters learning, selected attention
- Noradrenalin:
 - General attention, alertness, concentration
- Cortisol
 - Stress-hormone, low level – better memory
- Dopamine:
 - Stimulates motivation and pleasure centers



https://www.genetex.com/Research/Overview/neuroscience/neurites_synapses?srsIid=AYCX9vJ9OhpNVBlTXuICe1bZoJAWxdbxt5MUD8VNfHGA1zQUOQn1YIhU

Cognitive Gender Differences: The Psychobiosocial Approach

- Cognitive differences
 - Spatial Orientation & Mental Rotation
 - Language & Communication
- Neurobiological differences
 - Brain structure and functions
 - Hormones (especially estrogen, testosterone)
- Psychological aspects
 - Interests
 - Self-concept
 - Learning and working style
- Social influences
 - Family and role models
 - Socialization at school
 - Gender roles



■ Fig. 6.3 The psychobiosocial approach. Cognitive gender differences are based on complex interactions among biological, psychological, and social factors.

(Lautenbacher et al., 2007)

Gender Differences in the Brain

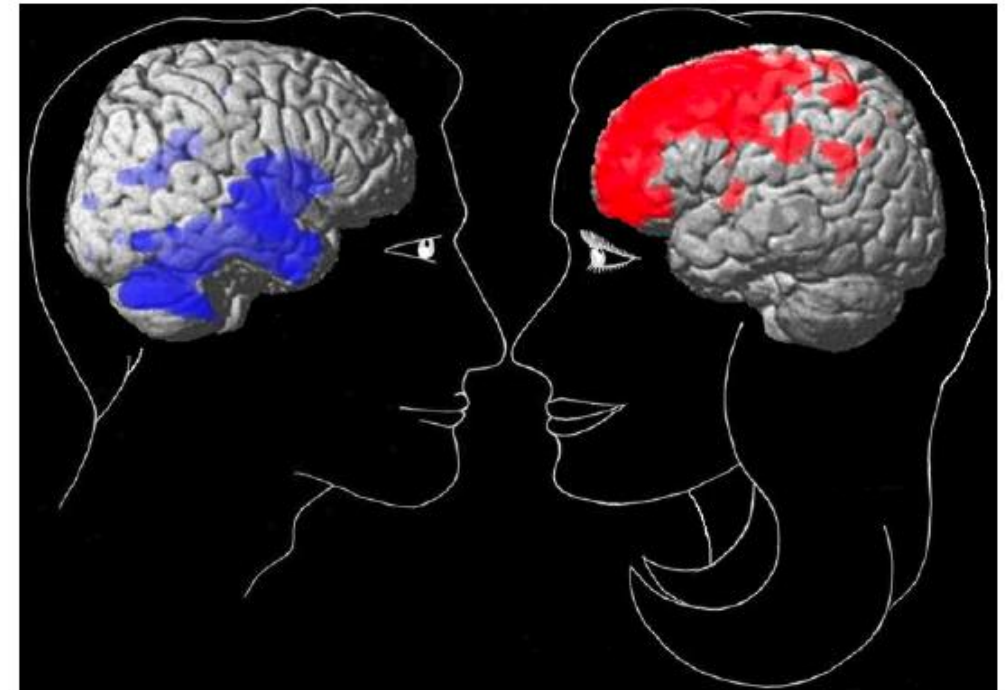
- Girls develop faster
- Language aptitude and empathy are female
- Math and spatial intelligence are male
- Hormones influence talents and performance
 - Higher estrogen – better verbal performance
 - Lower estrogen – better spatial orientation
 - Aptitude & performance vary in female hormonal cycle
 - Higher testosterone – better memory
 - Lower cortisol level during sleep – better long-term memory
- Brain structure is different – Females:
 - Thicker corpus callosum (connection brain hemispheres)
 - Language procession distributed in both hemispheres
 - Broca & Wernicke area proportionally larger
 - Higher density of neurons in Wernicke-Area



Differences in the Brain Structure

Sex differences in brain structure.

Areas with significantly larger regional gray matter volumes in men are depicted in blue, areas with significantly larger regional gray matter volumes in women in red. Original data acquired by Belinda Pletzer.



Brain Development (1)

- 0 – 1 years: capability of learning every language
- 1 - 3 years: grey matter = main structure of brain, more than necessary
- 3 – 6 years: more grey matter in prefrontal cortex (Planning, organization, concentration)
- 6 years: brain has already 90 % of final size
- 6 – 12 years: more grey matter in posterior parts, development of verbal skills and spatial intelligence
- Girls develop earlier

Brain Development (2)

- > 12 years: capability of language learning decreases
- Adolescence (15 – 20 years):
 - brain under reconstruction
 - Pruning – up to 50 % of synapses disappear - Use it or lose it!
 - White matter: Myelination – myelin layer gets thicker, faster stimuli transfer
- Surge in growth of prefrontal cortex
- Hormones influence talents and performance
 - Estrogen – verbal and spatial intelligence
 - Testosterone & cortisol – memory

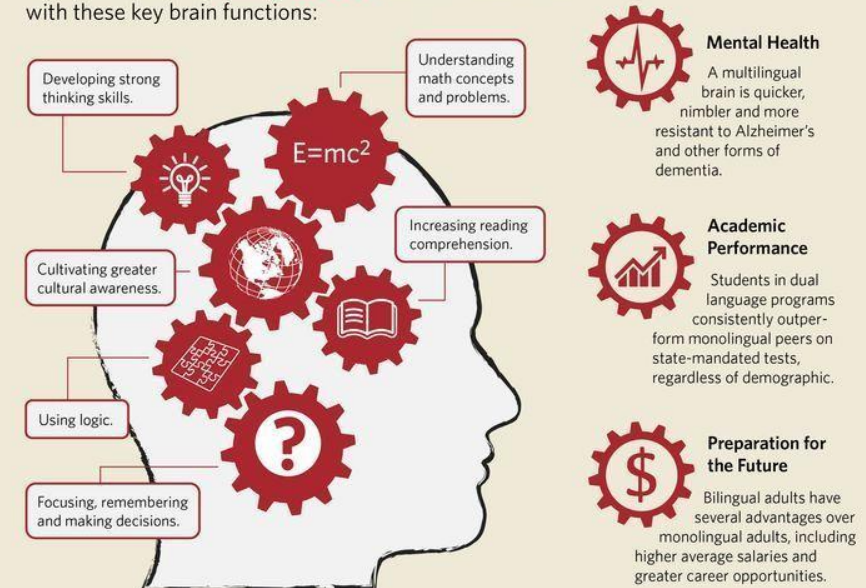
L2 Increases Learning Capacity

- Language learning engages neural circuits and plasticity to support broader learning capacity (Foisy, 2022; Gros et al., 2015; Houdé, 2011).
- Language experience interacts with executive control networks to influence attention, working memory, and learning efficiency (Clément et al., 2006; Foisy, 2022; Houdé, 2011).
- Early and diverse linguistic experiences leverage brain plasticity to facilitate subsequent cross-domain learning (Bentahar, 2015; Kolinsky et al., 2018; Romdhane et al., 2003).

Benefits of a Bilingual Brain

Splash language immersion programs provide a unique and powerful opportunity to strengthen children's highest cognitive brain potentials through deliberate literacy development in two languages and authentic exposure to rich language experiences.

Research shows that **bilingual people** have an easier time with these key brain functions:



Language in the Brain

Research also shows that the brains of bilingual people are more developed in areas that organize and process speech.



HOW MUSICAL TRAINING SHAPES THE BRAIN

INCREMENTS IN STRUCTURE AND FUNCTION
MUSICIANS COMPARED TO NON-MUSICIANS

FRONTAL LOBE

INCREASED GREY MATTER VOLUME
superior, medial, inferior frontal gyrus
– executive functions

INCREASED fMRI ACTIVATION
primary & supplementary motor areas
– motor preparation and execution

Broca's area – speech production

TEMPORAL LOBE

INCREASED GREY MATTER VOLUME &
INCREASED fMRI ACTIVATION

Heschl's gyrus – primary auditory cortex,
pitch perception

superior temporal gyrus – auditory
processing

INCREASED MISMATCH NEGATIVITY (EEG)

BASAL GANGLIA & LIMBIC SYSTEM

INCREASED GREY MATTER VOLUME

hippocampus – memory formation & retrieval

INCREASED EEG RESPONSE

temporal-limbic areas – emotions and memory

PARIETAL LOBE

INCREASED GREY MATTER VOLUME

primary somatosensory cortex – touch perception

INCREASED fMRI ACTIVATION

supramarginal gyrus – syntax processing
and attention

WHITE MATTER TRACTS

INCREASED WHITE-MATTER INTEGRITY

corpus callosum – connects brain hemispheres

corticospinal tracts – connect motor areas with
spinal cord

short fibres – connect sensory and motor areas

striatum – motor planning and reward perception

OCCIPITAL LOBE

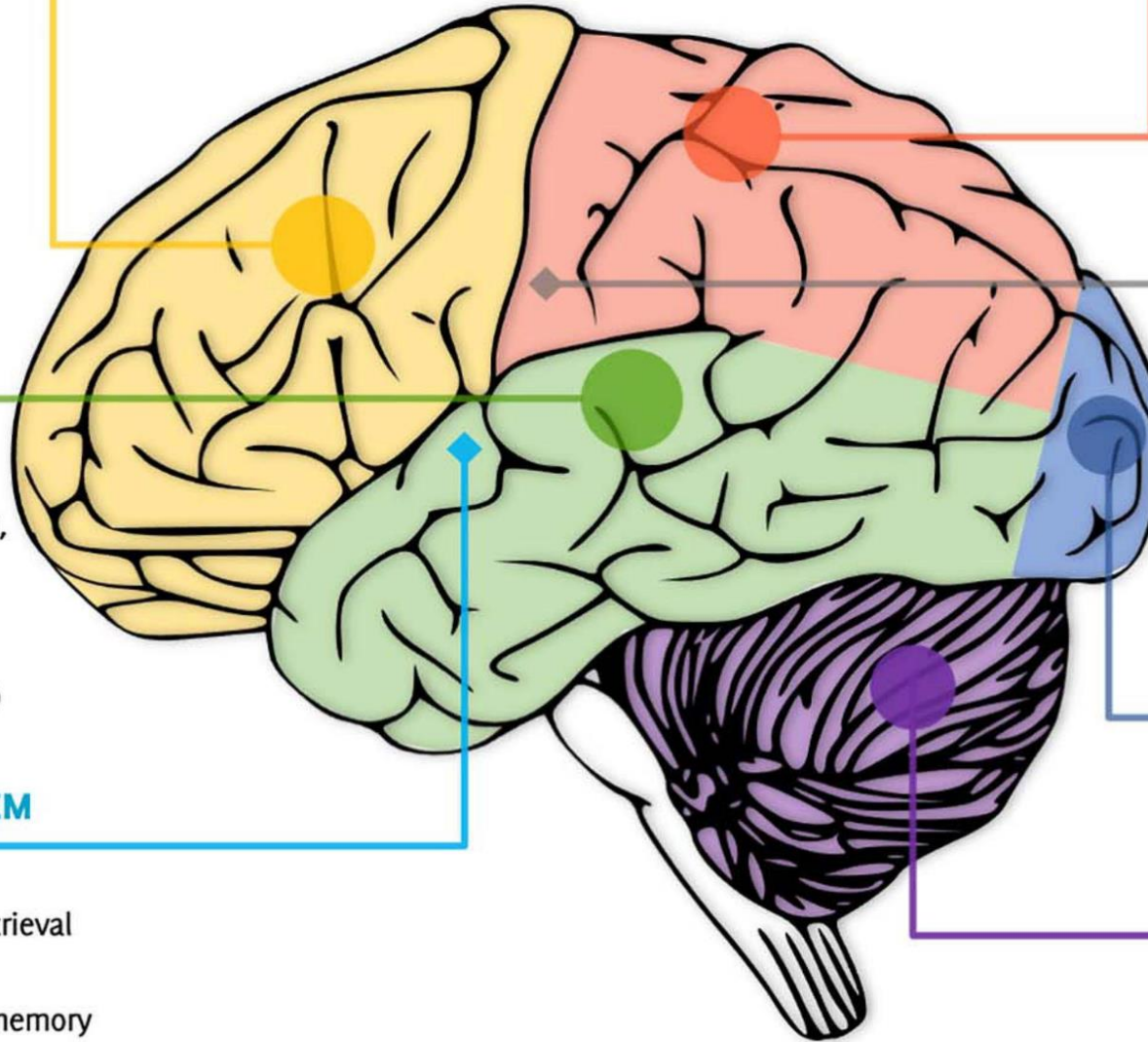
INCREASED GREY MATTER VOLUME

lingual gyrus – score reading

CEREBELLUM

INCREASED GREY & WHITE MATTER VOLUME

movement coordination and motor learning



Neurodidactics – the most important things in brief

Learning **MUST**
make sense à
Reference, work out
benefits

Curiosity +
Discovery =
Dopamine & Reward
Expectation

The brain is a **mirror**.
Imitation learning

**Automatic pattern
recognition** & rule
extraction.
Exploratory learning

4 eyes see more
than 2. **Cooperation**

Two is better!
Multimediaeffect

"Learning while you
sleep".
Consolidation

Best Practice: COOLIT & Brain-based Programming

Improving Understanding of Programming

Enhancing Learning Outcomes in
Bachelor Programming Courses

The Project

- Development of
 - A brain-based **teaching concept** for programming courses (nominated for Ars docendi 2013 - National Award for excellent teaching at Universities)
 - Appropriate **teaching material** as a self-learning booklet
- Evaluation of
 - Acceptance and satisfaction
 - Learning outcomes

	Experimental groups (EG)	Control groups (CG)
Pilot Project 2012/13	1 EG (n=21, n _f =7, n _m =14)	6 CG (n=105, n _f =29, n _m =76)
Extended Project 2013/14	3 EG (n=71, n _f =24, n _m =47)	4 CG (n=88, n _f =37, n _m =51)

Course Organization

- Students act according to competencies
 - Professionals = Peer tutors, peer teachers
 - Amateurs = sometimes peer tutors
 - Beginners
- Lesson structure in each unit (90 – 120 min.)
 1. Question phase (ca. 10 min) in groups with 1 peer tutor
consider previous knowledge, recall = re-storage
 2. Discovery phase (10-20 min) in groups with 1 peer tutor
Pattern recognition, learning rhythm (memory consolidation)
 3. Laboratory (Pair-Programming)
Practice makes perfect, recall = re-storage
 - (lecture max. 20 minutes only if and where necessary)

Teaching Methods & Tasks

- Reading exercises for discovery learning
 - Reading corner (complete program code and guiding questions),
 - Puzzles of program code
 - Step-by-step tutorials and exercises
 - Short tasks including a sample solution
- Competence-oriented tasks for cooperative learning
 - Mini exercises
 - Solutions
 - Peer tutoring
- Programming exercises for independent practice
 - Short complete programs, topics of every day life
 - Parts of a complex semester topic

Dis

```
public class sum {  
    public static void main (String[] args) {  
        int a = 5, b = 3;  
        int c = a + b;  
        System.out.println("a    = " + a);  
        System.out.println("b    = " + b);  
        System.out.println("c    = " + c);  
    }  
}
```

Output:
a = 5
b = 3
c = 8

```
public class mult {  
    public static void main (String[] args) {  
        int a = 3, b = 2;  
        int c = a * b;  
        System.out.println("a    = " + a);  
        System.out.println("b    = " + b);  
        System.out.println("c    = " + c);  
    }  
}
```

Output:
a = 3
b = 2
c = 6

1. Which parts (lines / terms) are necessary in all Java-programmes?
2. Can you discover the structure of a Java programme?
3. How do we have to indicate the name or title of the programme?
4. How does a Java programme begin, how does it end?
5. What do these two programmes calculate?
6. How can we get an output?

READING EXERCISES 2: READING CORNER – CLASSES AND OBJECTS

Reading Corner Student

```
public class Student {  
  
    private String name;  
    private boolean awake;  
  
    public Student(String name) {  
        this.name = name;  
        this.awake = false;  
    }  
  
    public String getName() {  
        return this.name;  
    }  
  
    public void setName(String name) {  
        this.name = name;  
    }  
  
    public void wakeUp() {  
        this.awake = true;  
    }  
}
```

Class Student

Student
- name : String - awake : boolean
+ Student(name : String) + wakeUp() + getName() + setName(name : String)

```
public class Day {  
  
    public static void main(String[] args) {  
        Student object1 = new Student("Jamie");  
        Student andy = new Student("Andreas");  
        Student randomName = new Student("Naomi");  
  
        object1.wakeUp();  
        andy.wakeUp();  
  
        randomName.setName("Melanie");  
        System.out.println(randomName.getName());  
    }  
}
```

Class Day - Main

Fig. 3. Reading corner “Student’s day”

EXAMPLE TASKS FOR THE READING CORNER

1. Read the example classes and write a “cheat sheet” including the main information about classes and objects.
2. Mark the constructor in the class *Student* and its parameters. Which variables does it set? Which methods has the class *Student*? What are they doing?
3. How many objects are generated in the *main*-method (class *Day*)? What are their names?
4. How do the objects change? What will the console display?

Results: Acceptance

- + Students & teachers liked **relaxed atmosphere** in the courses.
- + Learners & peer tutors appreciate the possibility to **get help** anytime and from different people.
- + **Free choice** concerning tasks, topics and material.
- + Most useful methods: **discovery learning, peer tutoring, pair programming** and teamwork.
- + Most useful tasks: all forms of discovery learning: **step-by-step** tasks, reading corners, video-tutorials, mini exercises & **solutions**
- + **Peer tutors learned more** than in a traditional setting: even contents exceeding the frame of the actual course content because they had to check the in books or to ask the teacher.
- The preparation of different material is too **much work** for teachers.

Verbal Feedback 2013

(n = 15/21)

Very positive comments, mentioned several times

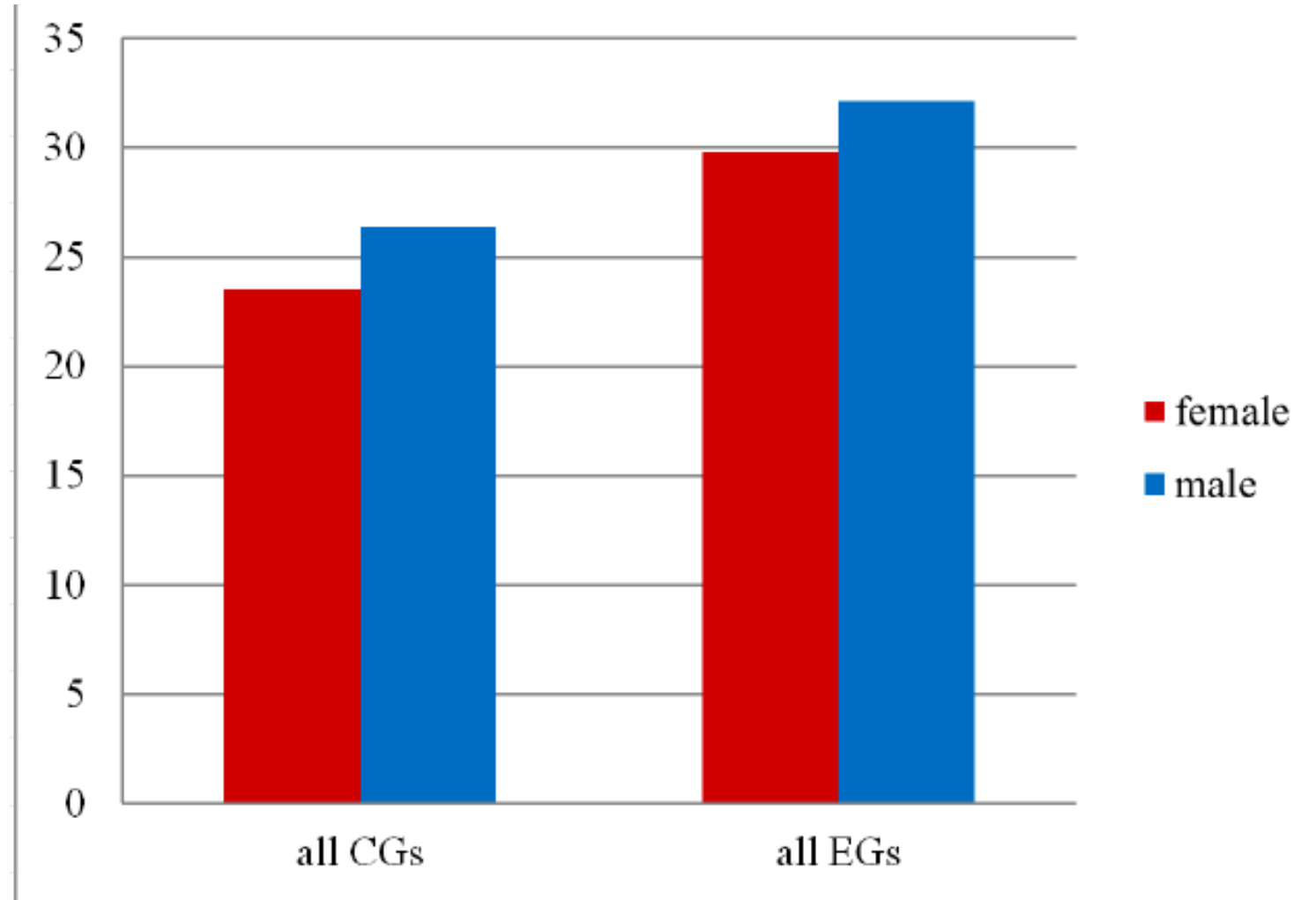
- Free, self-organized Learning (12)
- Peer tutors (11)
- Always possible to ask and get help (10)
- Super atmosphere in the course (8)
- Mini-exercises & solutions are very useful (5)
- Reading exercises are useful (4)
- Working in groups (4)
- Division in professionals, amateurs and beginners (1)

Wishes and suggestions

- None, good as it is (10)
- Should be continued! (4)
- More step-by-step and mini-exercises (1)
- Other courses with this concept (1)

No negative comments

Learning Outcomes 2014



Total average points (both exams, max. 50, less than 25 = failed)

Exams 2014

- Higher **success rate** in the EG: 52% (usually 40%)
- Significantly **better results** (achieved points) in the first exam (t-test for independent groups, $p = 0.008$, Cohens $d = 0.42$)
- Better results (points) in the second exam:
 - average in EG: 10.73 (CG 8.82)
 - standard deviation in EG: 6.98 (CG 8.64)
- Female students benefit even more:
 - **no** more significant **gender difference** in brain-based groups;
 - significantly better results for males in control groups: Cohens $d = 0.58$).

Exam Results 2014

- Significantly better results (achieved points) in the first exam (t-test for independent groups, $p = 0.008$, Cohens $d = 0.42$)
- Female students benefit even more (**no** significant **gender difference** in brain-based groups; significantly better results for males in control groups: Cohens $d = 0.58$).
- **Better results** (points) in the second exam:
average in EG: 10.73 (CG 8.82)
standard deviation in EG: 6.98 (CG 8.64)
- Higher **success rate** in the EG: 55% (usually 30-40%)

Mid-term Exam Average Points

Group	N	M	SD	T	p	Cohens d ¹
EG	71	20,80	5,38	2,65	0,009	0,42
CG	88	17,98	7,76			

Mid-term Gender

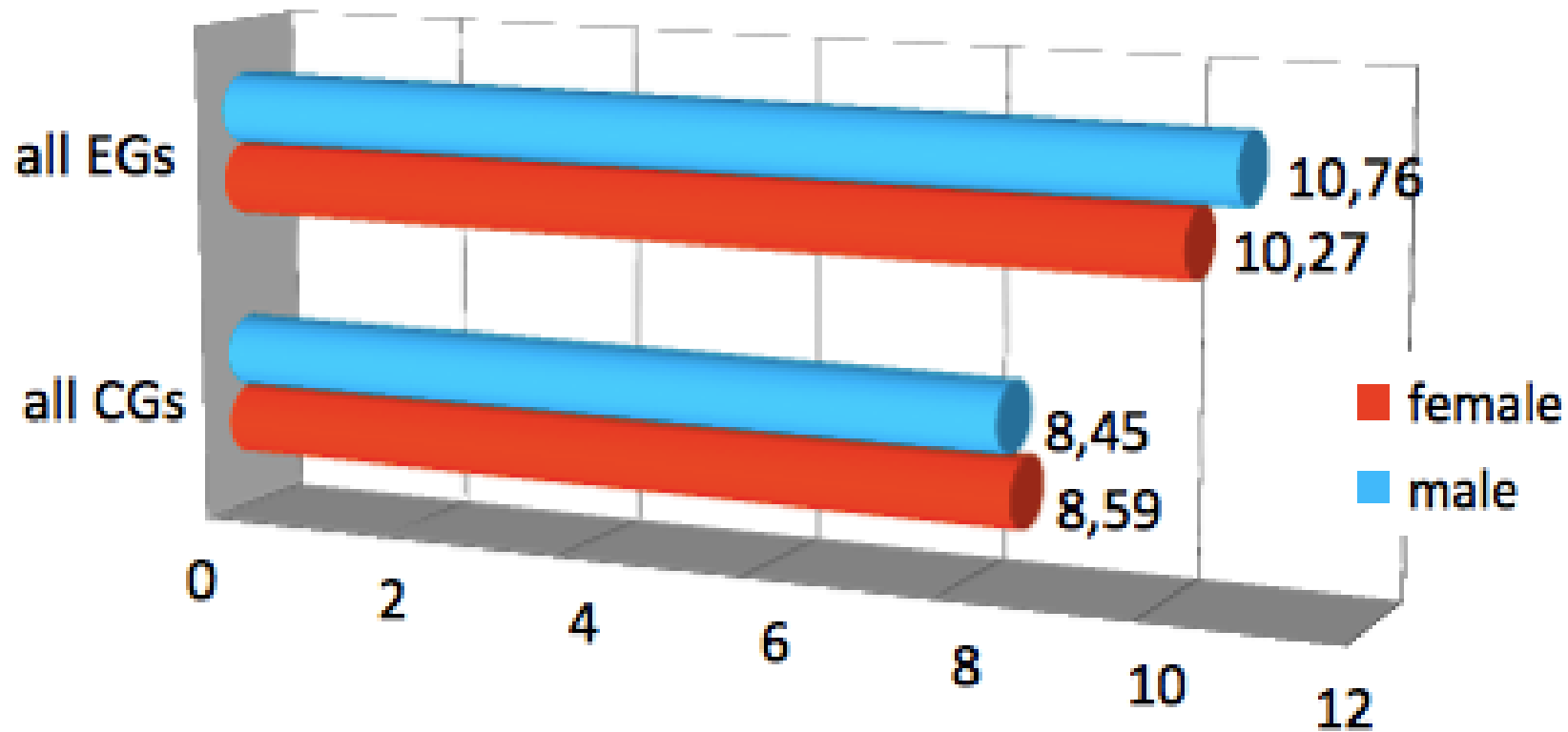
TABLE 3: GENDER DIFFERENCES IN CONTROL GROUPS (ACHIEVED POINTS)

<i>Sex</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>T</i>	<i>p</i>	<i>Cohen's d¹</i>
<i>male</i>	47	19,85	6,70	2,52	0,014	0,58
<i>female</i>	36	15,54	8,45			

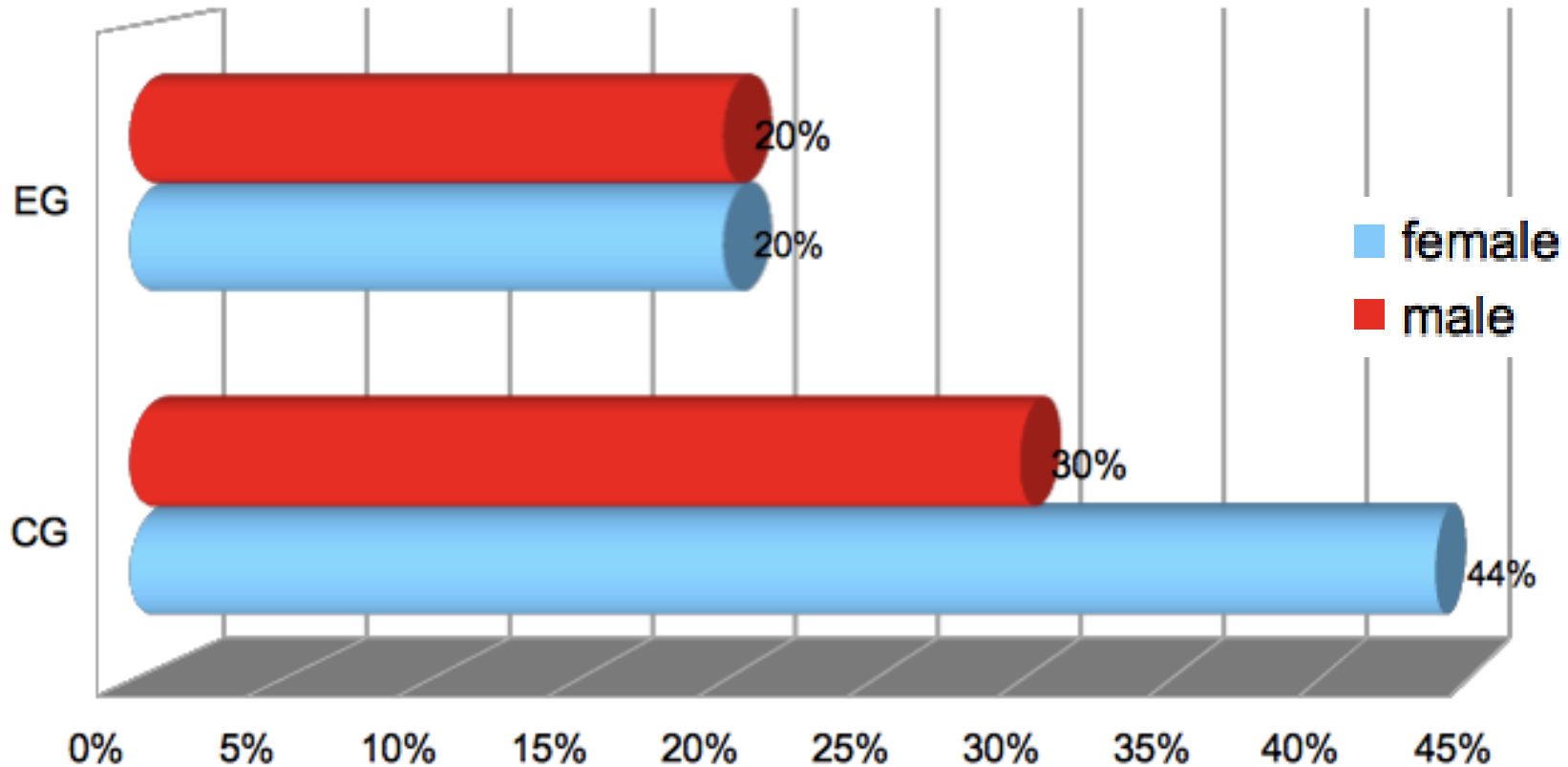
TABLE 4: GENDER DIFFERENCES IN EXPERIMENTAL GROUPS

<i>Sex</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>T</i>	<i>p</i>	<i>Cohen's d</i>
<i>male</i>	46	21,85	5,47	1,25	0,214	-
<i>female</i>	25	19,72	5,14			

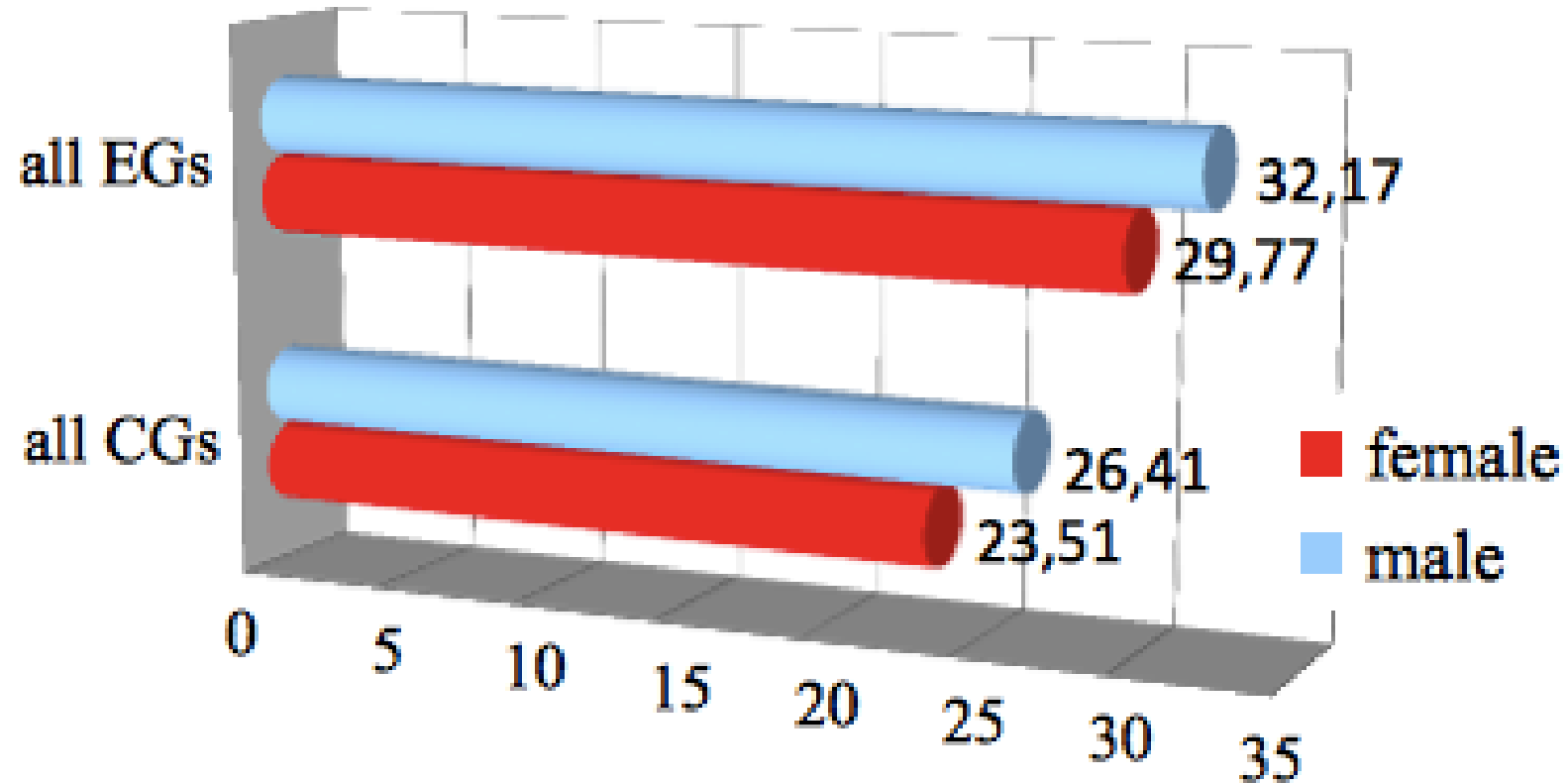
Final Exam Average Points



Dropout in % of Mid-term Exam

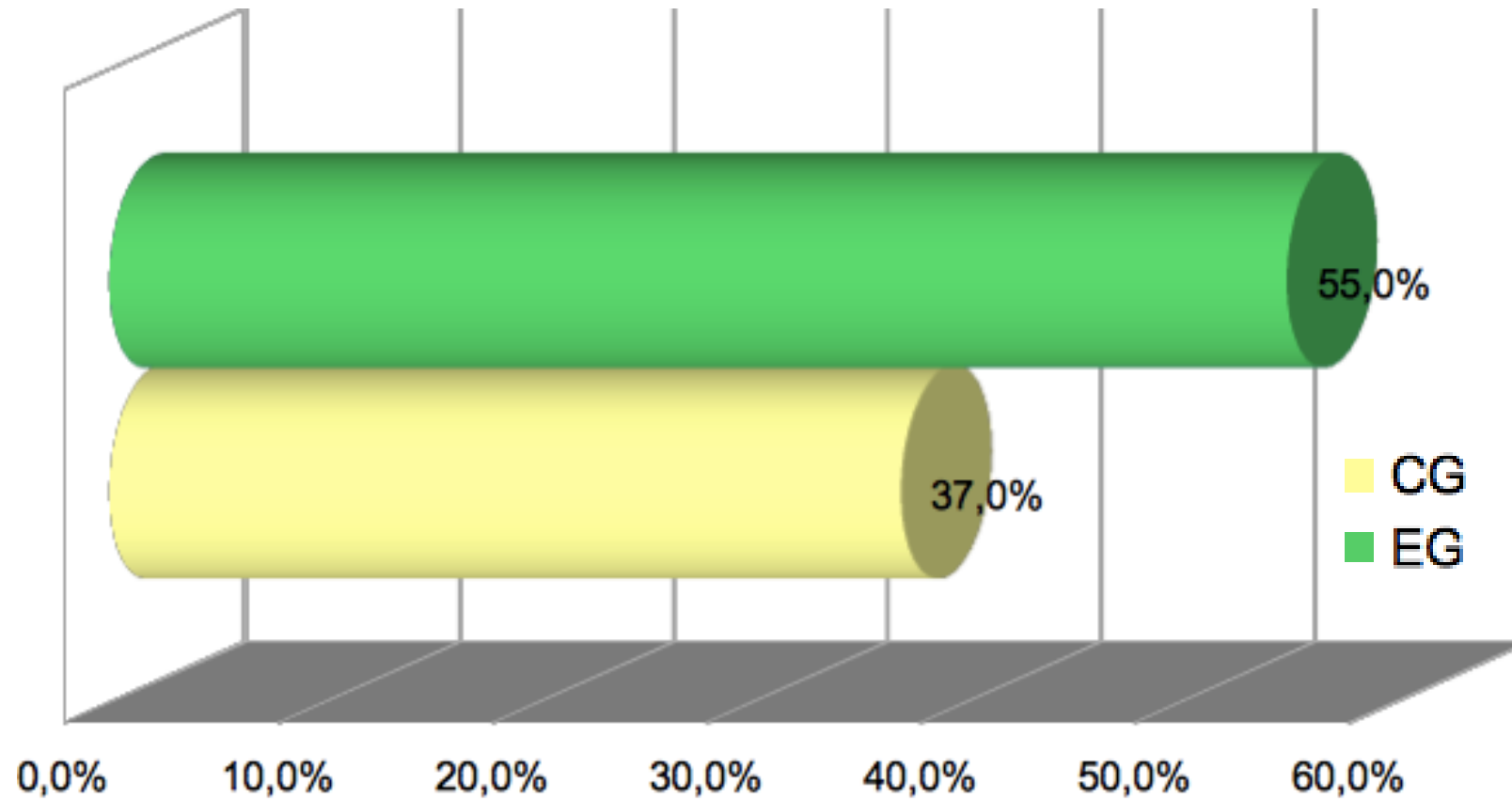


Total Average Points



Total average points (both exams, max. 50, less than 25 = failed)

Final Positiv Grades in %



Literature

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