III International Scientific Symposium “Intelligent Solutions”

Analysis of cognitive biases with EMOTIV brain-computer interface

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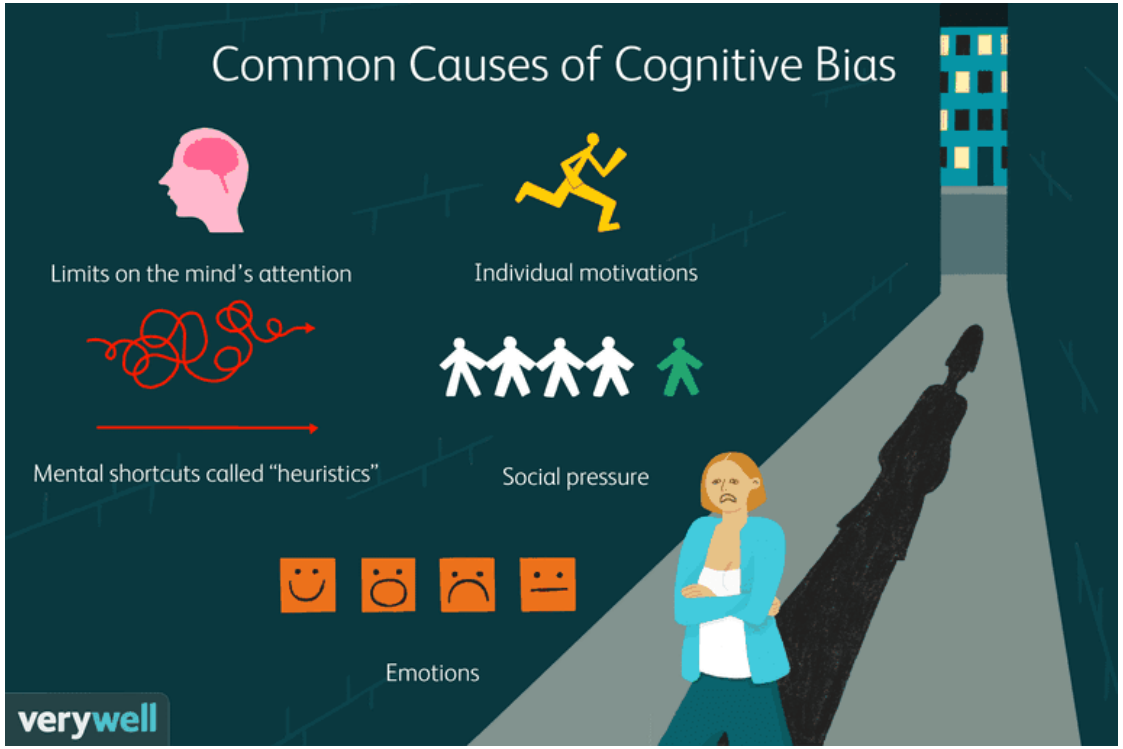
Intro

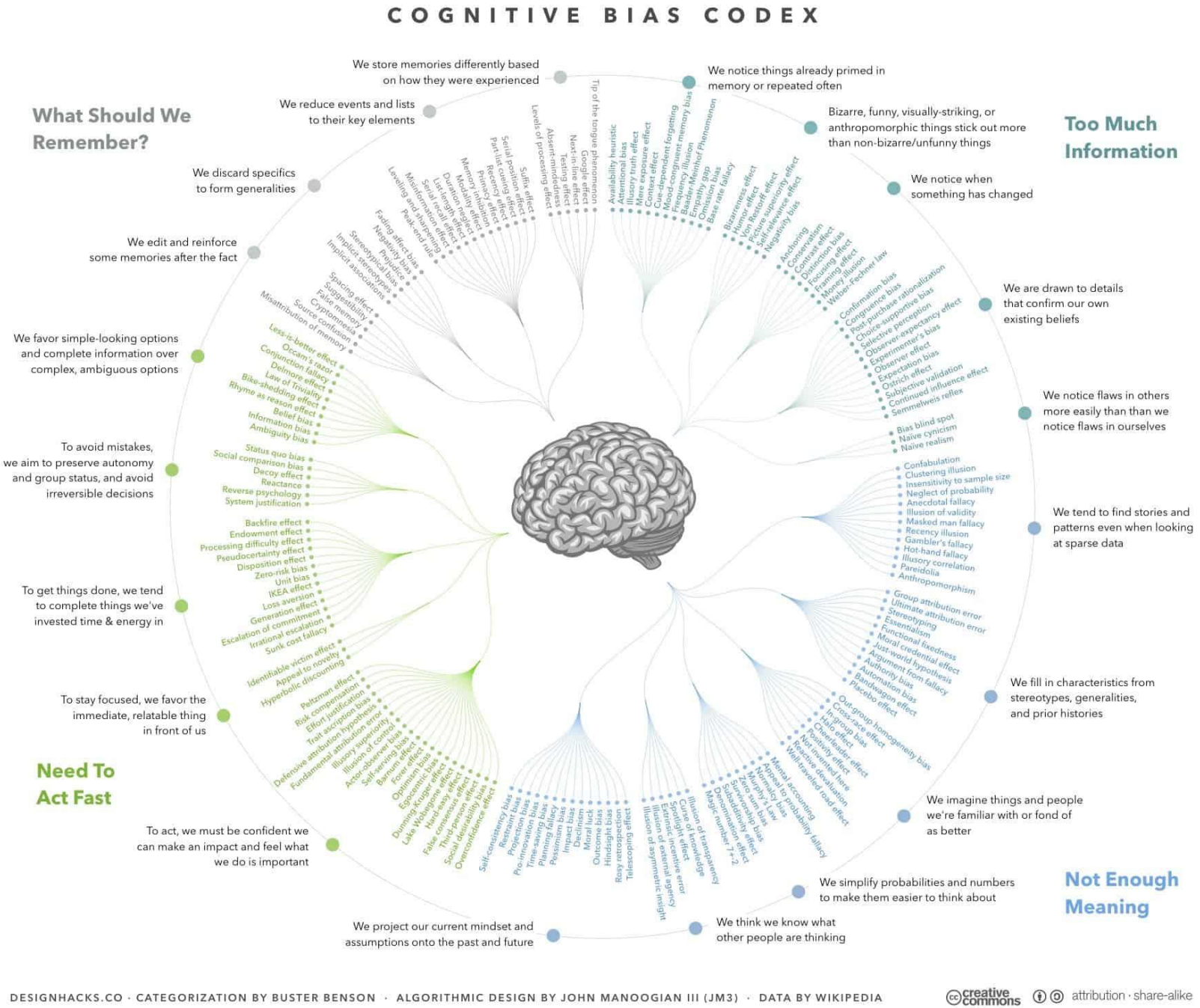
- A cognitive bias is a systematic pattern of deviation from norm or rationality in judgment. Individuals create their own "subjective reality" from their perception of the input. An individual's construction of reality, not the objective input, may dictate their behavior in the world. Thus, cognitive biases may sometimes lead to perceptual distortion, inaccurate judgment, illogical interpretation, and irrationality



#Wikipedia

Cognitive Biases are deviations from normal logical decisions, because of unconscious cycles or loose of control

State of the problem



Experience

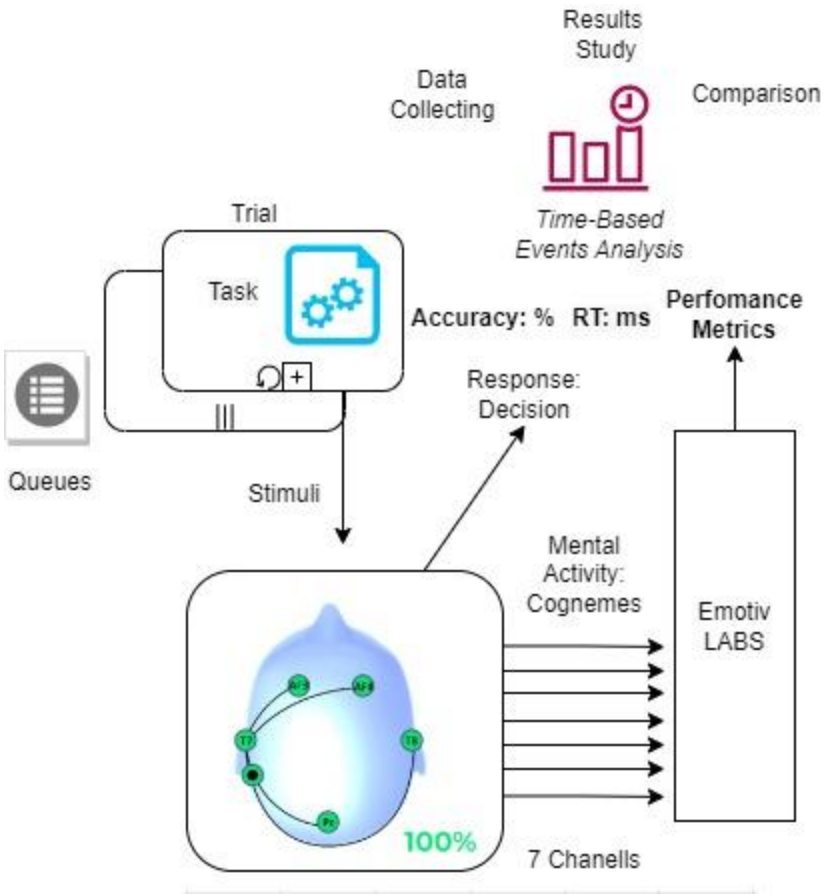


Fig 1. Session Scheme

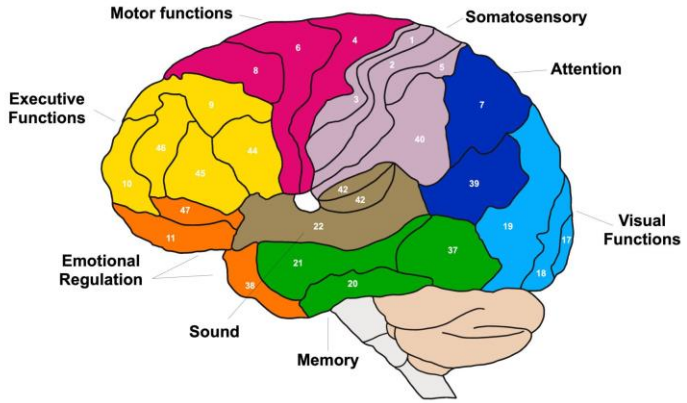
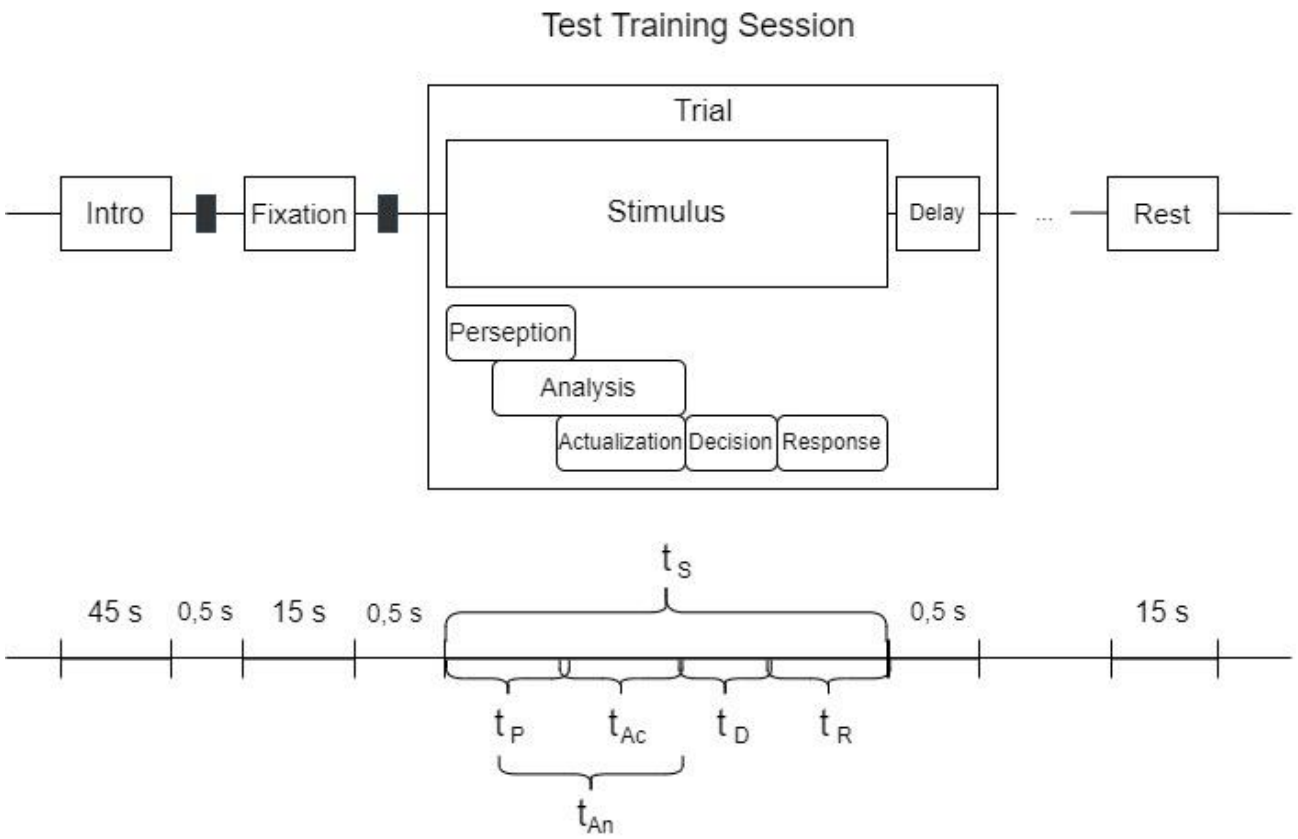
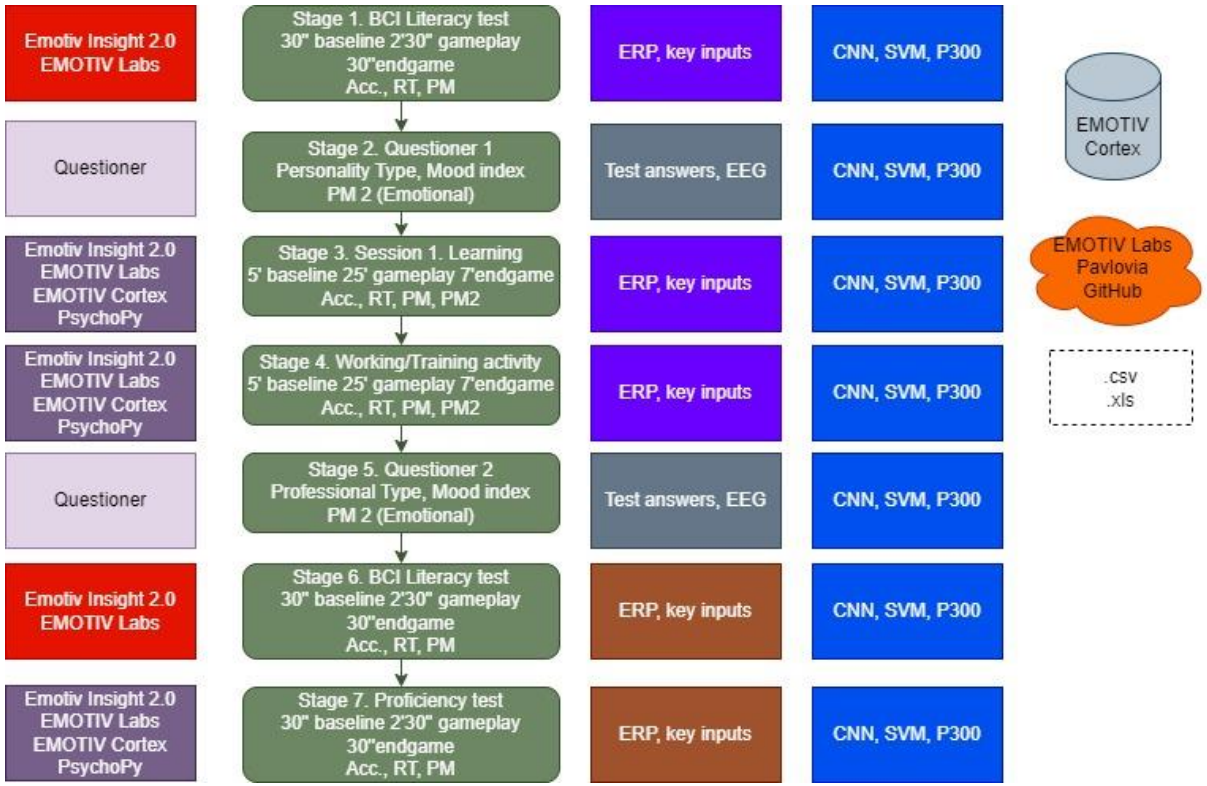


Fig 2. Improvised Laboratory. Emotiv Insight 2.0 headset

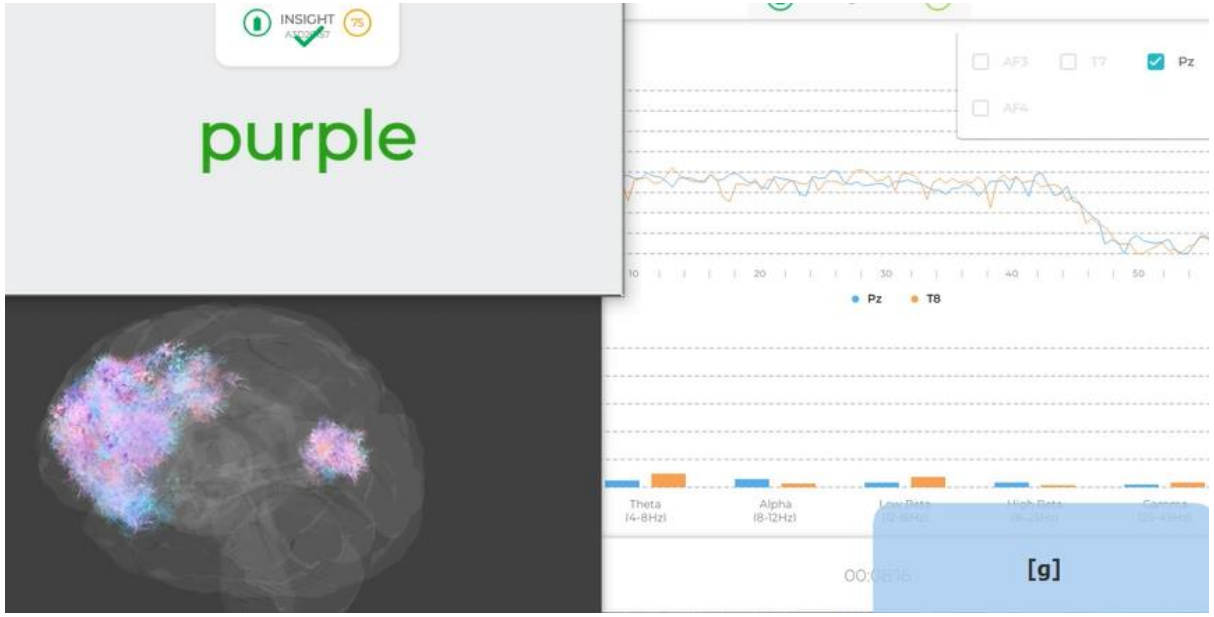
Session Design

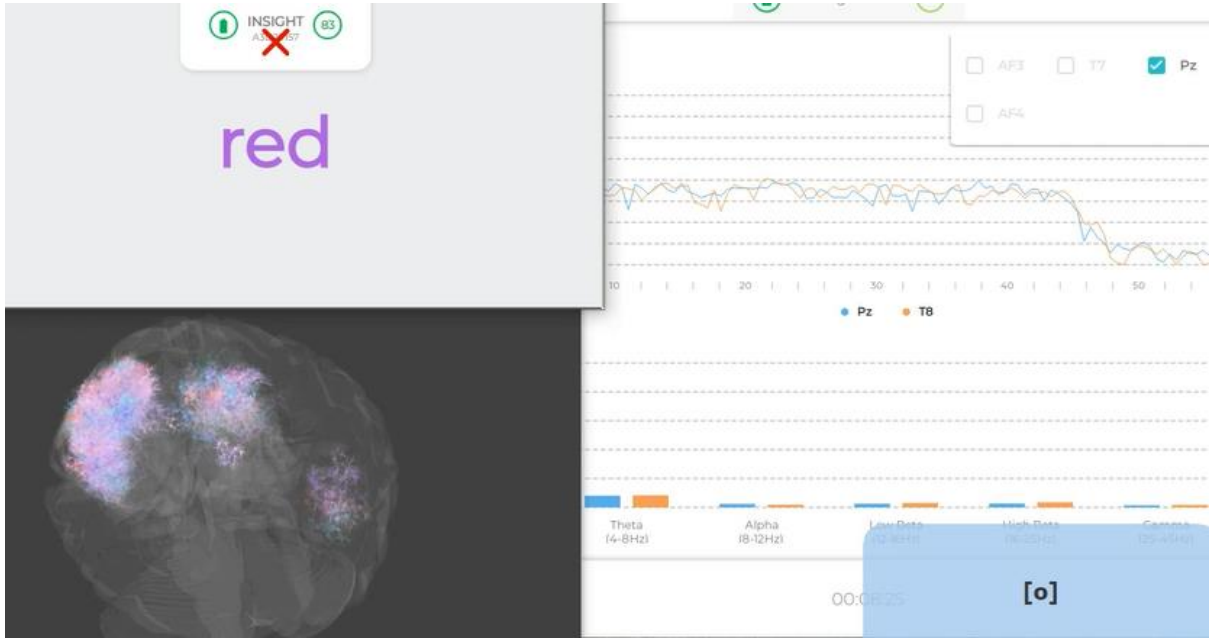


Data collecting process and technologies



Acc. is for accuracy, RT – response time, PM – performance metrics (attention, engagement, cognitive stress), PM2 – emotional performance metrics (excitement, focus, relaxation). ERP (event-related potentials) – technology used for computation of RT and PM changes according to actions (key inputs).

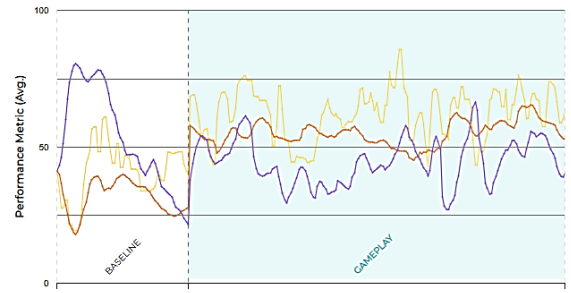




Performance Metrics This Session

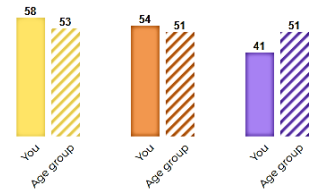
Your session in detail

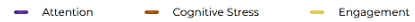
Click through the phases to see averages in each metric.



Average levels during gameplay

Your results vs your age group (20-29) results.

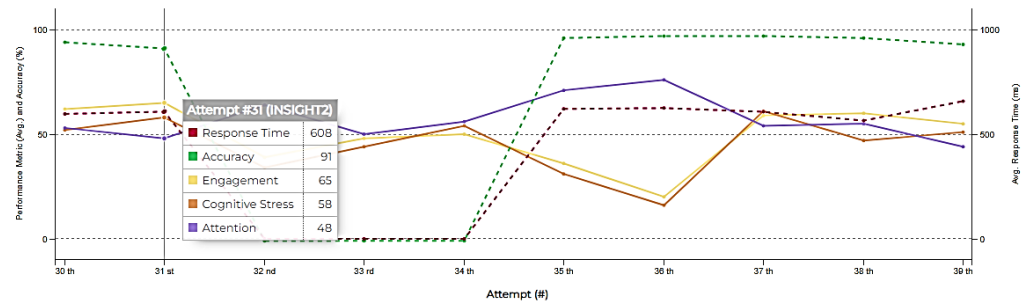


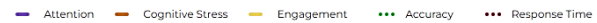


Performance Metrics and Behavioral Performance Over Time

Your progress in detail

Your progress over past attempts, recorded during Gameplay.



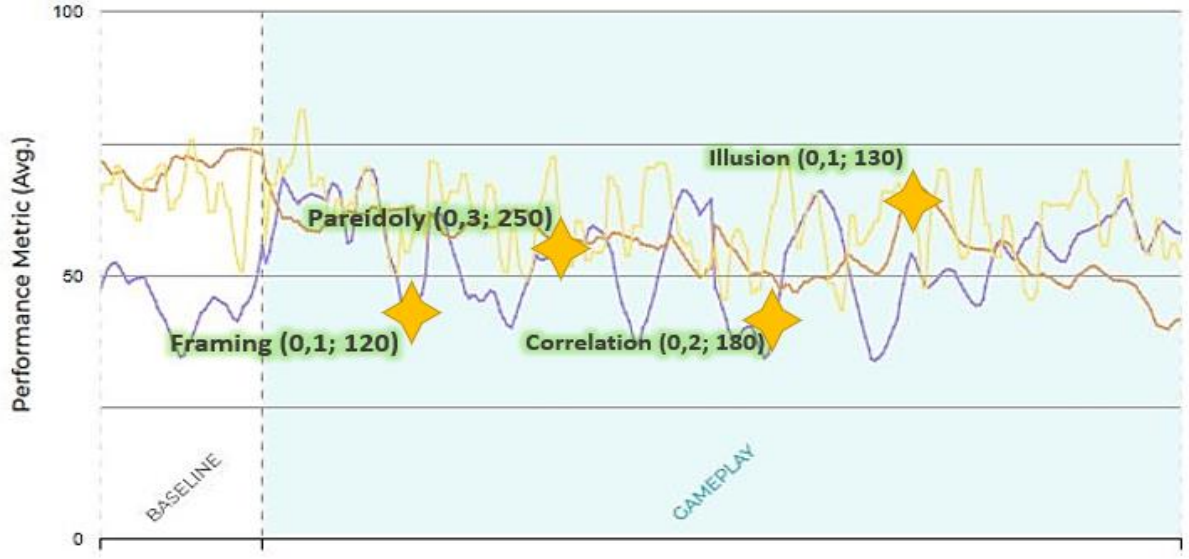


Performogramme Analysis

Recognition of Cognitive Biases

- Based on Performance Metrics
- Psychological Tests
- And Students Self-Analysis

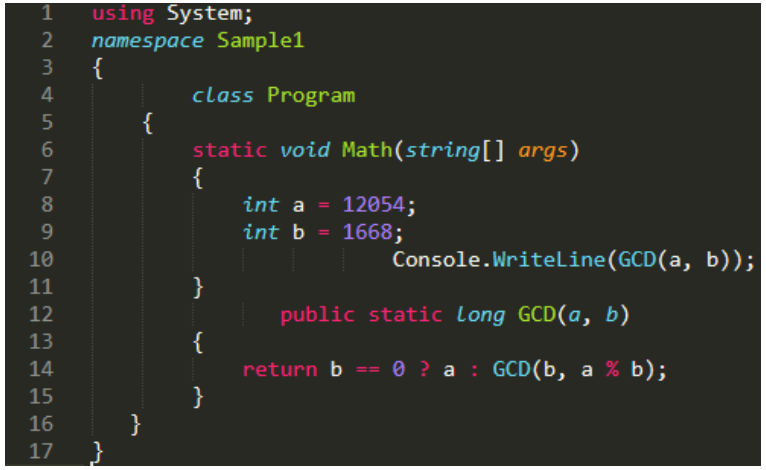
Task N	1	2	3	5	6	7	9
Descript.	Code	Value	Graphics	Formal	Term	Value	Array
Type	a	a	b	c	f	c	d
RT ms	889	675	753	659	821	743	650
Accur.	0,99	0,99	0	0,50	0,99	0,50	0,99



Session Design

- Professional task example

Stimulus



```
using System;
namespace Sample1
{
        class Program
    {
        static void Math(string[] args)
        {
            int a = 12054;
            int b = 1668;
                        Console.WriteLine(GCD(a, b));
        }
                public static long GCD(a, b)
        {
            return b == 0 ? a : GCD(b, a % b);
        }
    }
}
```

Description
Classification
Translation: 30 sec for primary
+during answering (for eyetracking sessions)

Answers Set:

{“This code have no errors”; “Greatest Common Divisor of two numbers must be a result of program”; “in 12 line a and b must have int index before”; “The result of program is 6861”; “No right answers”}

Answer Type: voice input, or spacebar for “true” and next for “false”

Time limitations
For answer: 2000ms

Resulting
RT 1200ms average
Acc. 80%
25 participants
25 min sessions 8
Testing period 1 month
Average number of tasks: 10

Collections of Data

- Stimuli (text, code, picture, formula etc.)
- Stimuli mode (voice, visual)
- Answer Sets (True/False)
- Answer Types (Spacebar/Next, Input, Mental Command)
- EEG
- Performance Metrics

Table 1. Types of Biases

Bias Type Description	Examples	Reasons	Representation
Perception			
Non-adequate perception of stimuli	"R" for green "red" in Stroop test Cluster illusion	Need for fast answers, incorrect performance prioritization[2]	Associative variants Increasing engagement, loosing of attention
Attention			
Deviation of results or errors because of lack of attention and focus	Concentration on form against quality	Tiredness, effort, brain inertia[3]	No answer in time Incorrect answer Loosing of attention Low engagement
Memory			
Non-adequate or absence of results	Loosing details, incorrect calculation or comparison	Tiredness, effort, need to rest, unconscious cycles, lack of time	No answer in time Incorrect answer Low engagement
Motivation			
Loose of control and flow, apathy, boredom	Fast unemotional pressing keys without immersion in task and performance	Loosing of flow state, depression, stress	No answer in time Incorrect answer Participant don't remember situation Hight cognitive stress Low engagement Low attention

Description and Evaluation of Biases Influences

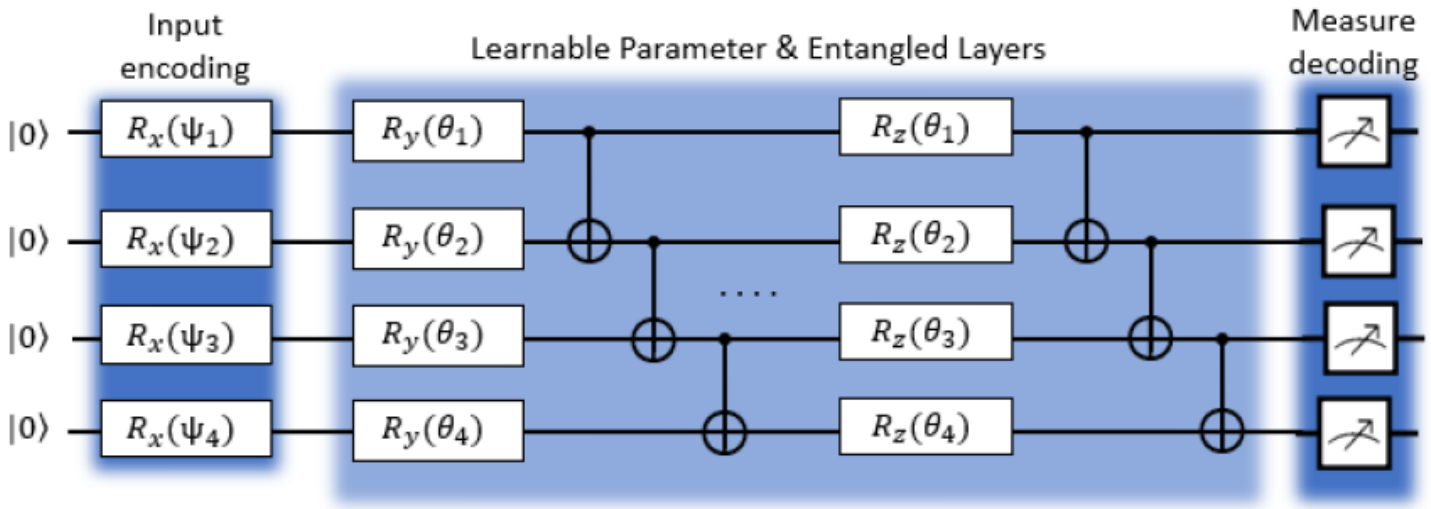
- Decision
- Solving
- Bias (Duration; Intensity; Point of Session; Number of Task; Performance Metrics)
- Normal (average) Indexes of Performance

E.g. 21 min of session. 4th test (Stroop effect), 20-22s, 25th Task (orange; green), Answer: g; Acc. 0 (out of time); Attention decrease from 38 to 21, Engagement decrease from 42 to 23, RT 1008 ms, Cognitive Stress 35 (average norm). Participant don't remember own state and decision progress. Reason: tiredness. Biases: motivational (0.78), attention (0.55), perception (0.54), memory (0.64).

$$CB_{RT} = \frac{RT - RT_{norm}}{RT_{norm}} \qquad CB_{Acc.} = \frac{Acc. - Acc._{norm}}{Acc._{norm}} \qquad CB_{PM} = \frac{PM - PM_{norm.}}{PM_{norm}}$$

$$Np_{eff.} = \frac{Acc.}{RT}$$

Quantum neural network



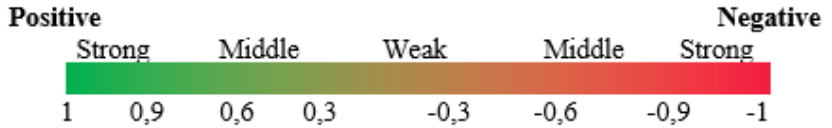
Quantum neural network can be used for efficient system design. In quantum computation $|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \|\alpha\|^2 + \|\beta\|^2 = 1$ is a two-dimensional complex vector normalized representation for a single qubit state, where $\|\alpha\|^2$ and $\|\beta\|^2$ are the probabilities of observing $|0\rangle$ and $|1\rangle$ from the qubit, respectively. Geometrically represented using polar coordinates θ and ϕ as $|\psi\rangle = cos(\theta/2)|0\rangle + e^{i\phi}\sin(\theta/2)|1\rangle$, $0 \leq \theta \leq \pi$ and $0 \leq \phi \leq \pi$ for mapping the qubit state into the surface of Bloch sphere. A multi qubit system can be represented as the tensor product of n single qubits, which exists as a superposition of 2^n basis states from $|00 \ldots 00\rangle$ to $|11 \ldots 11\rangle$. Quantum entanglement appears as a correlation between different qubits in this system. For example, in a 2- qubit system $\frac{1}{\sqrt{2}}|00\rangle + \frac{1}{\sqrt{2}}|11\rangle$, the observation of the first qubit directly determines that of the second qubit. Rotation operator gates $R_x(\theta), R_y(\theta), R_z(\theta)$rotates a qubit state in Bloch sphere around corresponding axis by θ and controlled-X gate entangles two qubits by flipping a qubit state if the other is $|1\rangle$.

Biases Evaluation with Pearson correlation

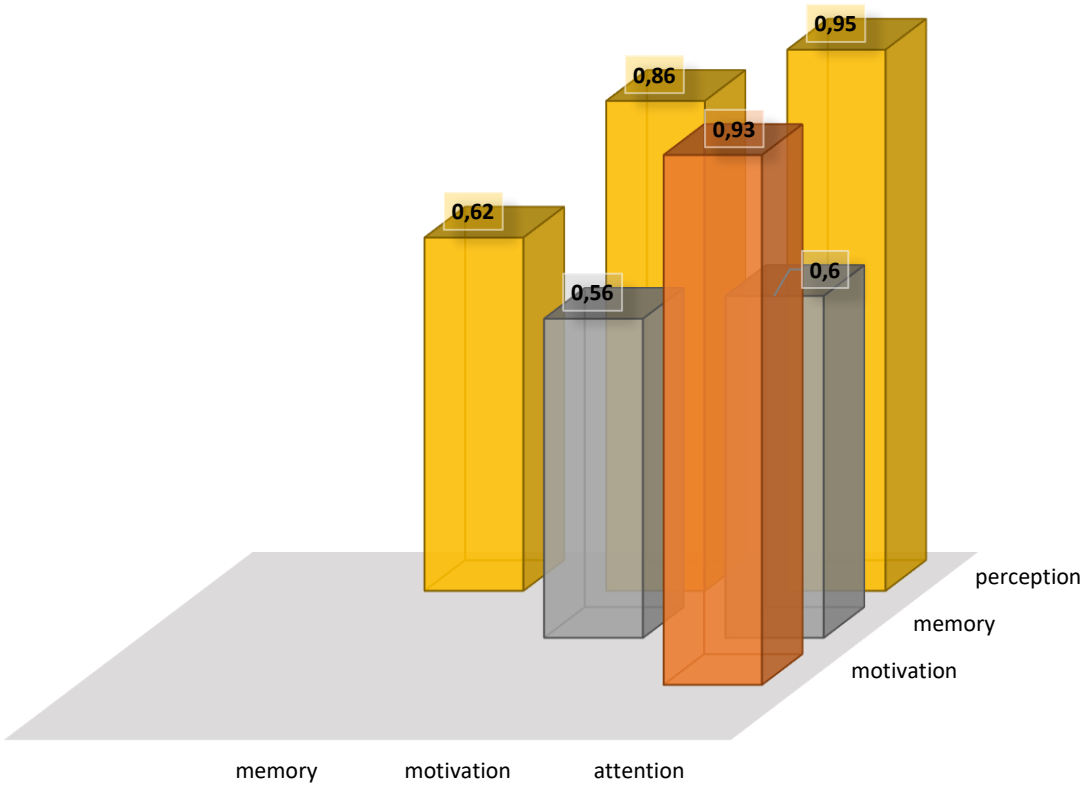
	Perfomance Metrics						Results		Cognitive Biases				
	engageme	exitemen	**attention**	cognitive	relaxation	focuse	accuracy	RT	CB a	CB mot	CB mem	CB p	Er
engageme	1	-0,0559	0,644918	0,082158	-0,12587	0,205005	0,350854	0,211451	-0,03871	-0,0511	0,389968	0,183497	-0,43355
exitemen	-0,0559	1	-0,2507	0,578352	0,108253	-0,6758	-0,45661	-0,20336	0,653532	0,752051	0,425803	0,583194	0,189509
attention	0,644918	-0,2507	1	0,009165	-0,42666	0,364133	0,577791	0,744991	-0,49826	-0,55215	-0,15241	-0,24669	-0,7226
cog. stress	0,082158	0,578352	0,009165	1	-0,32409	-0,81771	-0,44368	0,324871	0,651685	0,681013	0,202724	0,7483	0,18917
relaxation	-0,12587	0,108253	-0,42666	-0,32409	1	0,104595	-0,0719	-0,76956	0,105802	0,144866	-0,00866	-0,05436	-0,02614
focuse	0,205005	-0,6758	0,364133	-0,81771	0,104595	1	0,707731	-0,00551	-0,77941	-0,75762	-0,4301	-0,7526	-0,48703
accuracy	0,350854	-0,45661	0,577791	-0,44368	-0,0719	0,707731	1	0,156902	-0,83693	-0,75545	-0,57058	-0,74973	-0,87199
RT	0,211451	-0,20336	0,744991	0,324871	-0,76956	-0,00551	0,156902	1	-0,22234	-0,34182	-0,19462	-0,01628	-0,28198
CB a	-0,03871	0,653532	-0,49826	0,651685	0,105802	-0,77941	-0,83693	-0,22234	1	0,93214	0,603255	0,952479	0,701777
CB mot	-0,0511	0,752051	-0,55215	0,681013	0,144866	-0,75762	-0,75545	-0,34182	0,93214	1	0,560034	0,867028	0,60515
CB mem	0,389968	0,425803	-0,15241	0,202724	-0,00866	-0,4301	-0,57058	-0,19462	0,603255	0,560034	1	0,628384	0,481457
CB p	0,183497	0,583194	-0,24669	0,7483	-0,05436	-0,7526	-0,74973	-0,01628	0,952479	0,867028	0,628384	1	0,589062
Er	-0,43355	0,189509	-0,7226	0,18917	-0,02614	-0,48703	-0,87199	-0,28198	0,701777	0,60515	0,481457	0,589062	1

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Pearson correlation



Results



- This research is just introductive and very selective because of specific character of such investigations, technical conditions of equipment and software, possible condition of conscious observation and psychological features, but I suppose as it is valuable path in this field as these results will be useful for further researches and development of cognitive optimization of complex systems and human-computer interaction.
- Artificial part of interaction can be evaluated on efficiency by index of biasing as human part of interaction. In this case we should and general evaluation will help to evaluate index of efficiency of cognitive interaction.

Thank you for your attention!