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WHITE PAPER

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# Systematic Concealed Information Test — The Engramma system

## 1. TECHNOLOGY

Engramma is a state-of-the-art concealed information test (CIT) system for field use. With specific reference to autonomous nervous system reactions, it measures exosomatic DC skin conductance and beat-by-beat heart rate. It comprises 4 measurement channels, each producing 20 samples per second with 10 bit accuracy. The gathered data is analysed in real-time and saved in comma separated value (.csv) spreadsheet format for further extended analyses (e.g., Excel, Matlab). Measured data is also time-linked to concurrent video recording with sound. Engramma also comprises a questioning system with audio communication unit and multi-language speech synthesis to perform bias-less questioning.

## 2. CONCEALED INFORMATION TEST

A concealed information test (CIT) or guilty knowledge test (GKT) uses human physiological responses to detect concealed information. In the test, the subject is auditory or visually stimulated by multiple details of the issue under investigation, including relevant (connected to the issue) and neutral (fabricated) alternatives. The alternatives are selected so that a subject with no knowledge of the issue would not be able to discriminate the relevant one. Several physiological and behavioral indicators have been studied to detect the responses to the stimuli in association with CIT.

One of the earliest and most referenced CIT indicator is the change of skin conductance, or galvanic skin reaction (GSR). In 1959, D. Lykken was able to differentiate most guilty from innocent subjects (90% correct classifications) [1]. This finding has been successfully replicated numerous times across different laboratories [2].

Other indicators include reaction times, where familiar targets are recognized faster than unfamiliar targets [3]; electroencephalogram (EEG); heart rate; and blood perfusion in various organs. These changes occur within seconds of stimulus introduction. [4] EEG studies have corresponded particularly with the P300 wave and P3a component of the event-related potential (ERP). [5, 6]

Also pupillary dilation has been studied in CIT. There is, however, contradictory results. [7, 8, 9]. Furthermore, the muscle functions in the esophagus is studied in accordance to CIT [10].

A widely referenced and popular method to detect responses in CIT is to study and analyze audiovisual behavior of the subject. This means to observe and classify the facial expressions, body movements and posture, and speech tone and semantics. [11] The evaluation of these parameters, however, is a subjective process and it is very difficult to establish a consistent set of evaluation rules which would be observer independent.

Both the novelty and the importance of stimulus affects to the intensity of reaction. During exposure to neutral and emotionally significant new stimuli, both pleasant and unpleasant stimuli produce more intense responses than emotionally neutral stimuli. [4]

In response evaluation, an important feature is that the magnitude of the response diminishes with repeated stimulus presentations. [12] Likewise, habituation of the skin conductance response has been frequently reported in research on CIT. [13]

With repeated stimuli, the responses are diminished relative to first introduction, emotionally significant content diminishing at a slower rate. The differences between emotionally charged and neutral stimuli suggests the importance of emotion in reactions over novelty.[4]

## 3. PRACTICAL MEASURING OF PHYSIOLOGICAL SIGNS

The research results presented in previous chapter have been obtained in controlled tests performed in laboratories equipped with scientific measurement setup. To create a practical CIT device for field use, additional requirements must be taken into account:

- A set of most established and documented measurement methods
- physical contacts to the subject
- effective and consistent data processing and presenting
- immediacy of results
- use-case requirements
- instrumentation complexity and form factor of apparatus.

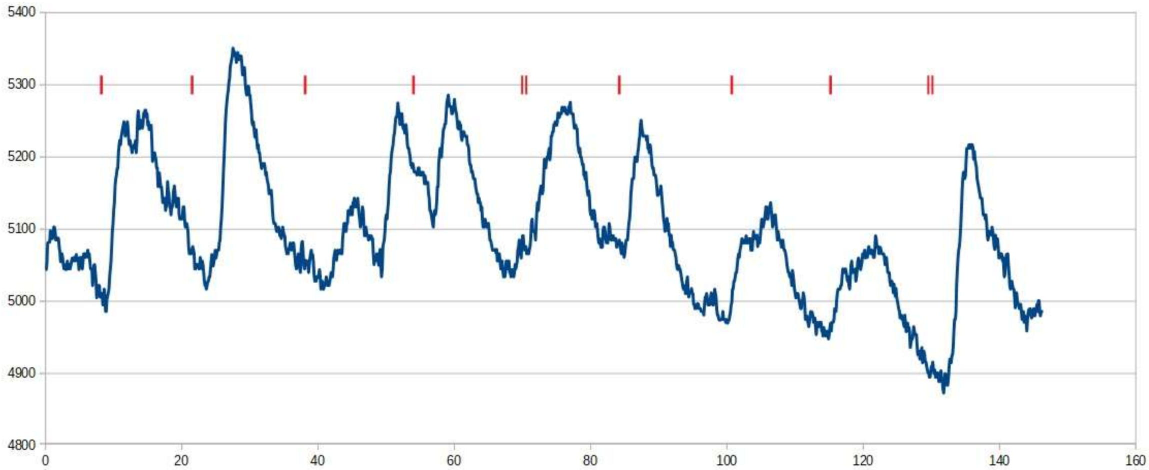
The most studied method which is also widely used in practical CIT systems is GSR. It is a de-facto standard used as a reference in research of most other methods. Furthermore, the measurement of GSR is relatively easy. However, the yielded signal is still analyzed with various methods, and plain visual analysis is mostly used. This paper introduces a novel presentation method to be used in field CIT.

GSR is measured galvanically with two electrodes applied to finger tips. This presents a moderate physical contact. With modern data processing methods, the CIT dependent signal can be extracted and presented in real time.

A practical system should also enable smooth questioning and objective parameters extraction and presentation. A complete CIT process comprises the question set development, the measurement session and the results analysis, which are of equal importance.

## 4. MEASUREMENTS IMPLEMENTATION

Engramma system measures the skin conductance using DC constant voltage method. The measurement voltage is 1,2 V. The skin contact is established using two Ag/AgCl electrodes. Electrode gel is recommended to establish a good conductivity. The skin conductance is indicated as variable $\mathbf{G_x}$ , expressed in nS (nanosiemens). Typical value of the skin conductance is in the range of 3000 to 10000 nS and the rise of $\mathbf{G_x}$ due to stimulus response is typically 0 to 500 nS.




Picture 1. Typical skin conductivity signal. Vertical scale is conductivity in nS, horizontal scale is time in seconds. Red bar depicts the moment when a stimulus is given.

Picture 1 presents a 150 second skin conductance measurement session. One can see that the conductivity is affected by the stimuli given. Due the stimulus, the conductance is rapidly rising for approximately two seconds followed by a slower decay.

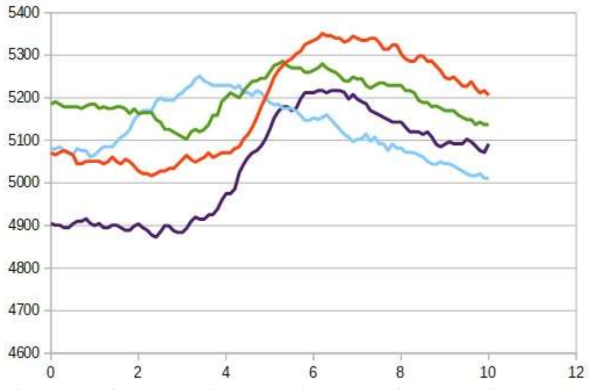
There are, however, anomalous responses due to subject self-induced emotions and other disturbances so the typical pattern is not always followed. Also the baseline of the curve is changing through the time which makes simple analysis methods inadequate.

Engramma measures the pulse with photoplethysmographic method. The pulse is detected from the fast changing part of the photoplethysmographic signal. Engramma shows the beat-to-beat pulse.

# 5. DATA PROCESSING

The measured GSR signal is affected by slow pace drift and other than CIT induced phenomena. Thus the response should be identified by a set of characteristics which are unique to CIT. Picture 2 presents a set of GSR responses, temporally normalized to the stimulus. Looking at Picture 1, it can be noted that the CIT response is characterized by a specific:

- delay from stimulus to response
- rate in conductivity rise
- temporal length of the reaction.




Picture 2. A set of reactions temporally normalized to the stimulus start. Vertical scale nS, horizontal scale seconds.

From Picture 2, it can be evaluated that the delay between stimulus and reaction is approx. 2.5 seconds, the rate of conductance rise is approx. 150 nS/s, and the temporal length of the reaction is approx. 2,5 seconds.

With these guidelines, a signal processing algorithm can be developed. As noted, the average level of the conductance has no importance but a distinctive indication of the detected response is needed. In Engramma the result is combined from the measured rate of conductance and the duration of the reaction.

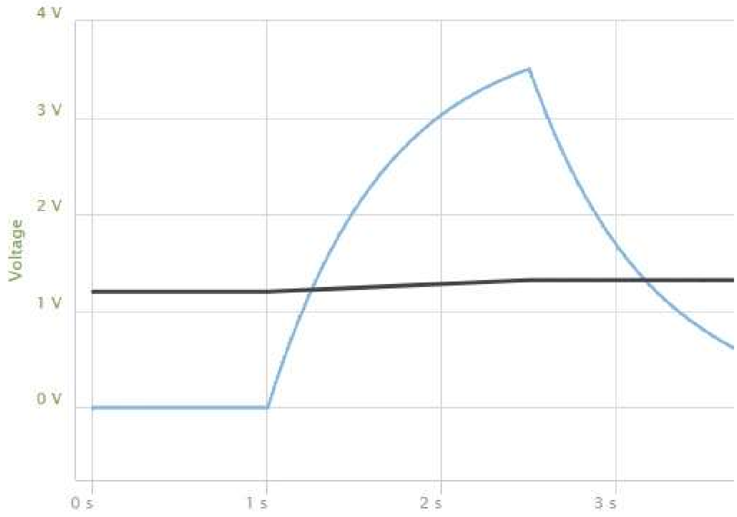
The graph presented is formed using a formula

$$V(t) = V_{ref}\left(1 + Ao \cdot dG_x\right)\left(1 - e^{-\frac{t}{\tau}}\right) \quad (1)$$

,

where **V(t)** is the displayed signal at the time **t** after the reaction onset; $\mathbf{V_{ref}}$ is the conductance measuring voltage ( $\mathbf{V_{ref}}$ = 1.2 V); $\mathbf{A_o}$ is the amplification factor (Ao = 5 $10^6$ Ω ); $\mathbf{dG_x}$ is the conductance change rate; e is the Euler's number (e = 2.71828...); and **τ** is the time constant of the circuit ( **τ** = 0,68 s). The final value of **V(t)** is

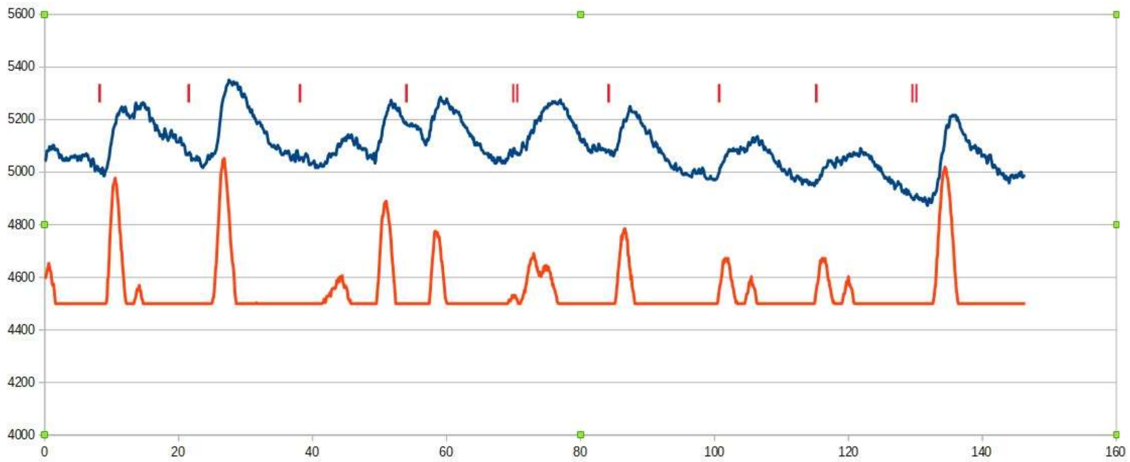
$$V(\infty) = V_{ref}\left(1 + Ao \cdot dG_x\right) \quad (2)$$




Picture 3. Repesentation of Formula (1). Blue line is V(t), the formula is valid in the range 1 s ... 2.5 s. Black line is $\mathbf{G_x}$ (not in scale).

As can be seen in Picture 3, the length of the reaction is 2,5 s and the **V(t)** graph has an exponential shape. The graph doesn't reach its final value before the reaction ceases. Formula 1 gives the maximum value reached with **t** equal to the reaction time, 1.5 s in the example.

The shape of the curve differs from theoretical shape in real measurement due to other influences to the response. In stable environment and co-operative subject, the response template is most prominent and the displayed result curve shows the CIT correlated data. In Picture 4, the **$G_x$** record seen in Picture 1 is added with the **V(t)** signal. The Formula (1) filters arbitrary fluctuations and shows the places of stimulus responses.




Picture 4. Typical Engramma result signal (red). Typical skin conductivity signal (blue). Vertical scale is conductivity in nS, horizontal scale is time in seconds. Red bar depicts the moment when a stimulus is given.

# 6. REFERENCES

[1] Lykken, D.: *The GSR in the detection of guilt.* Journal of Applied Psychology, 43 (1959), 385–388.
[2] Ben-Shakhar, G., & Elaad, E.: *The validity of psychophysiological detection of information with the Guilty Knowledge Test: A meta-analytic interview.* Journal of Applied Psychology, 88 (2003), 131–151.
[3] Verschuere, B. , Crombez, G. , Degrootte, T. and Rosseel, Y.: *Detecting concealed information with reaction times: Validity and comparison with the polygraph.* Appl. Cognit. Psychol., 24 (2010): 991-1002.
[4] Bradley, M.M.:*Natural selective attention: Orienting and emotion.* Psychophysiology. 46 (1): 1–11 2008.
[5] Rosenfeld, P. J., Cantwell, B., Nasman, V. T., Wojdac, V., Ivanov, S., & Mazzeri, L.: *A modified event-related potential-based guilty knowledge test*. International Journal of Neuroscience, 42 (1988), 157–161.
[6] Polich, J.: *Overview of P3a and P3b.* In J. Polich (Ed.), Detection of Change:Event-Related Potential and fMRI Findings (pp. 83-98). Kluwer Academic Press: Boston 2003.
[7] Lubow, R. E., & Fein, O.: *Pupillary size in response to a visual guilty knowledge test: New technique for the detection of deception.* Journal of Experimental Psychology: Applied, 2 (1996), 164–177.
[8] Robert M. Stelmack David A. T. Siddle: *Pupillary Dilation as an Index of the Orienting Reflex.* Psychophysiology 19(6):706-8 December 1982.
[9] Steiner GZ, Barry RJ: *Pupillary responses and event-related potentials as indices of the orienting reflex*. Psychophysiology. 2011 Dec;48(12):1648-55.
[10] Stacher, Georg: *The Responsiveness of the Esophagus To Environmental Stimuli.* In Psychophysiology of the Gastrointestinal Tract - Experimental and Clinical Applications. Hölzl, Rupert (Ed.) Springer 1983.
[11] Paul Ekman: *Lying and nonverbal behavior: Theoretical issues and new findings*. Journal of Nonverbal Behavior, September 1988, Volume 12, Issue 3, pp 163–175.
[12] Sokolov, E.N, *Neuronal models and the orienting reflex.* In The Central Nervous System and Behavior, Mary A.B. Brazier, ed. NY: JosiahMacy, Jr. Foundation, 1960, pp. 187–276.
[13] Ben-Shakhar, G., Frost, R., Gati, I., & Kresh, Y.: *Is an apple fruit? Semantic relatedness as reflected by psychophysiological responsivity.* Psychophysiology, 33 (1996), 671–679.