MindMiTM. Psychological Assessment System.

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1. Introduction

Human personality has been continuously investigated as a configuration of traits that reflect an individual's way of acting, feeling, thinking and adjusting to the environment. The continuous process of understanding human nature and nurture is vital for predicting an individual's way of acting in specific contexts and in different life areas such as work field, social interactions, family functioning or attitudes towards health. Psychological research is making progress in linking personality traits with specific actions and behaviors (e.g. Eysenck, 1991; Gray, 1987, 1991; Watson & Clark, 1992), looking for individual differences in brain anatomy and physiology, in bodily functions and self-regulation processes, in sensation and perception, in information processing and thinking styles, in behavior and emotion regulation, in interpersonal interaction and so on (e.g. Bandura, 2006; Block, 2002). Using biological (e.g. Nebylitsyn & Gray, 1972) and physiological data (e.g. Fowles, 1980; Carver & White, 1994; Crider, 2008), the connection between human personality traits and behavior is currently investigated through individual differences in brain functioning (Canli, 2006). A recent cybernetic model of global personality traits is examining how specific personality traits exert control over human behavior (Van Egeren, 2009; Wiener, 1948). These traits are seen as self-regulatory controls that underlie behavior patterns rather than manifest behavior itself (Crider, 2008). It seems that human beings mentally incorporate propensities of action into personality traits (Carver, 2005; Robins et al., 1996; Schneirla, 1959). These traits encode all the actions and controls necessary for a person to achieve a goal.

Although research in the field has made significant progress in explaining how personality and individual differences impact a person's behavior and adjustment to specific contexts, measuring these aspects of personality is far more complicated. Almost every field of applied psychology requires psychological assessment tools. In order for psychologists and specialists to play their key part in improving individual and group functioning, at almost every level, they need to rigorously assess the individual, the group of people or the organization they are working with.

The development of mathematical models and advanced processing methods based on neural networks, especially those used in cognitive systems psychology[1], or other advanced methods of real time analysis for functions with several variables, has led to the increasingly visible affirmation of the important role that *engineering* plays in psychological research. To highlight this reality, it is interesting to follow the implementation aspects of medicine, which provide instruments for diagnosis and treatment, or development and therapy, respectively. In this regard, implementation involves the transposition of phenomenology in a method or tool, a definite appeal to *engineering*, because *medical engineering*, for example (also called *bioengineering* or *biomedical engineering)*, interdisciplinary integrates professional activities of engineering with basic medical knowledge on the human body, as well as an understanding of how it works when healthy, sick or injured.

When studying the processes of perception, sensation, thinking, learning, cognition, emotion, motivation, personality, behavior, interaction between individuals and interaction with the environment, psychology will have allied disciplines such as anthropology and sociology (when studying social and environment influences on behavior), physics (in addressing vision, hearing and touch), or biology (in the study of the physiological bases of behavior).

Diagnosis in psychology is circumscribed to *psychometrics* as a field concerned with theory and technique of psychological measurement. *Psychometrics* is one of the main branches of *psychological cybernetics.* Being focused on measuring the results of scientific activity, it deals with the quantification of mental phenomena and intellectual capacities, using standardized and calibrated experimental methods. Therefore, it builds measurement tools and procedures, it develops and refines theoretical approaches of measurement, necessarily relying on extensive implementing activity that makes the evaluation technologies available to the psychometrician psychologist and beyond. The connection between a specific technology and the way to turn it into a testing instrument involves much more than psychology.

Just like in medicine, in psychology, implementation of a phenomenon in order to use it in a testing equipment involves the interdisciplinary integration of basic psychological knowledge regarding the human being, with professional engineering activities and an understanding of the difference between normality and pathology. This is the role of *psychological engineering*, concerned with studying the phenomenon, analyzing its relationship with the psychometric purpose of testing, establishing the type of model approach, establishing the relationship between the *dependent* and *independent variables* (in the case of statistical models), and creating an algorithm which will then be implemented in a specific and advanced testing equipment. Therefore, psychological engineering appeals to *cybernetic modelling* by formalizing a part or a whole psychological system and by developing theoretical models that treat it as a cybernetic system, thus resolving the functional relationship that involves understanding and applying a manifest mental phenomenon, and approaching specific mental aspects through quantification and

[1] The cognitive system is a neuromimetic network where information flows between processing units as activation values (D.A. Norman).

assessment, which is provided by *psychometrics.* As the concrete result of a complex engineering endeavor in the field of psychology, the psychometric system MindMi™ combines sensitive aspects of recent theories on personality and behavior analyzed from a biological model perspective, using the benefits of an inventive implementation based on the electrodermal response technique, solving the inferential equation all the way with experimentally confirmed results.

2. Modern theories in the psychology of personality and behavior

Exploring the autonomic and somatic motor aspects of cognitive functioning has a long history in the field of psychophysiology and has acquired a similar application in neuropsychology and cognitive neuroscience research (Cacioppo, Tassinary, & Berntson, 2000; Sarter, Berntson, & Cacioppo, 1996). Psychophysiological evaluation in normal and clinical population has contributed to the understanding of a wide range of relevant phenomena such as visual perception (Bauer, 1984; Tranel & Damasio, 1985), memory (Diamond, Mayes, & Meudell, 1996; McGlinchey Berroth et al., 1997), emotion (Bradley & Lang, 2000; Davidson & Sutton, 1995; Tranel & Hyman, 1990), or decision-making mechanisms (Bechara, Tranel, Damasio, & Damasio, 1996, apud. Schinka, Velicer, & Weiner, 2003). Organism-environment interactions may undergo a wide range of measurement methods, including electrodermal reactivity, pupillary responses, electromyographic changes, cardiovascular changes and their effects on hormonal and endocrine regulation (Schinka, Velicer, & Weiner, 2003).

One of the most widely accepted theories regarding a biological model in psychology is the biopsychosocial personality theory, proposed by Gray in 1970. Eysenck and Gray were among the first researchers who studied personality traits through their relationship with individual differences in brain functioning. They assumed that brain processes can be described under the umbrella of a conceptual nervous system, comprising key circuits that are relevant to personality and behavior (Matthews & Gilliland, 1999). Thus, empirical associations between personality and behavior can be derived from individual differences in brain functioning parameters. Eysenck took the biological personality traits into account and proposed the cortical arousal theory. He compared the level of arousal (physiological activation) with a scale of introversion - extraversion and used them to describe individual personality types and their corresponding behavioral patterns. Gray's theory began as a modification of Eysenck's theory and is more strongly anchored in physiological responses, having a strong scientific support from animal studies targeting different areas of the brain involved in different learning mechanisms (Canli, 2006). Gray proposed two control systems of behavioral activity (Gray, 1982, 1985a,b): the *behavioral inhibition system* and the *behavioral activation system*. *The behavioral inhibition system* is a neuropsychological system related to sensitivity to punishment and aversive (avoidance-related) motivation, which inhibits motor behavior (Fowles, 1980). This system is recognized for its attempt to relate pharmacological, neuroanatomical, neurophysiological and behavioral aspects in one theory. According to Gray, the behavioral inhibition system has its neural bases in the septal area of the limbic system and in the hippocampus (the septo-hippocampal system and its interconnected structures). The theory assigns functions to each area of the system and to the ascending noradrenergic pathways afferent to these areas (Puente & McCaffrey, 1992).

The *behavioral activation system* corresponds to sensitivity to rewards and appetitive (approach-related) motivation, being related to the individual's disposition of pursuing and achieving his goals. The BAS initiates behavior in response to the stimuli conditioned for reward (approach-related), or to avoid punishment (active avoidance). The physiological mechanism for BAS is associated with the catecholaminergic and dopaminergic pathways in the brain.

3. EDA phenomenology in theories of personality and behavior

The Autonomic Nervous System is part of the Peripherical Nervous System and serves primarily as a regulatory function, helping the body to adapt to internal and environmental requirements, thereby maintaining homeostasis. There are a variety of measurements that can be used to assess changes in the activity of the Autonomic Nervous System. Electrodermal activity (EDA) is a method frequently used to evaluate the activity of the autonomic nervous system, with a long history in psychological research. Different personality traits were investigated using psychophysiological measurements (Cacioppo & Tassinary, 1990), such as electrodermal activity. the electrodermal response is seen as a peripheral manifestation of neural activation (Crider, 2008), driven by requirements of cognitive capacity (Murray & Kochanski, 2002).

The measurement of the electrodermal response takes place on the eccrine sweat glands, which are scattered over a large area of the body, but concentrated mainly on the palms and soles. The sympathetic branch of the autonomic nervous system innervates these sweat glands, where, unlike in most responses of the autonomic nervous system, the main neurotransmitter involved in changes is acetylcholine and not epinephrine (Mendes, 2009 in Harmon-Jones & Beer, 2009). Placing electrodes on the skin, especially in the palmar surface of the hands, is an ideal way to monitor the autonomic nervous system (Öhman, Hamm, & Hugdahl, 2000) through the sweat glands, controlled by the sympathetic nervous activity. In this case, neurosignals are collected in direct current (DC), using two electrodes subjected to a very small electrical potential difference, a measurable electric current is set between them, and the defined sizes are the phasic and tonic conductance. SCL *(Skin Conductance Level)* represents the tonic or basal skin conductance, a conductance level that is manifest in the absence of any external stimulus. SCL is expressed in microSiemens and falls generally in the range of 10-50 microSiemens. Phasic conductance or SCR *(Skin Conductance Response)* arises in the presence of an external stimulus (visual, auditory, tactile, etc.) and represents an increase in skin conductance, which can last up to 10-20 seconds, followed by a return to SCL. In the literature (Edelberg, 1968), it is mentioned that these SCR responses can occur spontaneously, without any external stimulus, with a frequency of 1-3/min, considering that there are so called *electrodermally labile* persons, who have a high frequency of SCR and a slow adaptation to simple stimuli repetition, and *electrodermally stable* persons, with rare spontaneous reactions and fast habituation. These differences are considered to be related with a number of psychophysiological variables, epidermal lability and stability representing fundamental differences in the characteristics of individuals.

Using peripheral measurements in the context of emotion, motivation and attention has revealed important empirical evidence for social and personality psychology (Pennebaker, Hughes, & O'Heeron 1987; Wegner, Broome, & Blumberg, 1997; Murphy, Steele, & Gross, 2007; Olsson et al., 2005). Changes in skin conductance can index emotional responses even before awareness of the emotion. An example of the fact that physiology can provide information on emotional and motivational responses before their awareness is provided by Bechara and colleagues (Bechara et al., 1997, apud. Mendes, 2009).

According to Crider (2008), electrodermal activity increases when the behavioral inhibition system is activated. Also, studies show an inverse relationship between electrodermal lability and expression of emotional and antagonistic impulses. An increased EDR lability is associated with an undemonstrative and agreeable disposition, while high EDR stability is associated with an expressive and antagonistic disposition (Crider, 2008; Fowles, 1980). This is consistent with Block's distinction between *undercontrolled* and *overcontrolled* personality types (Block, 2002), with overcontrolled people being described as emotionally undemonstrative, shy and agreeable, and undercontrolled people being described as expressive and antagonistic (Robins et al., 1996).

The distinction between undemonstrative and agreeable EDR labiles versus expressive and antagonistic EDR stabiles contradicts the general expectation of a positive relationship between behavioral intensity and sympathetic nervous system activation. Jones (1950) proposed a distinction between an *internalized,* versus *externalized model of emotional expression*. Specifically, when behavioral expression is blocked due to social pressure or other reasons, emotional impulses could be expressed by a high sympathetic activation. Therefore, electrodermal lability may be interpreted as an internalized way of emotional expression when the externalized expression is inhibited. Electrodermal lability can act as a psychophysiological marker for individual differences in the effortful control of emotional expression and antagonistic behavior (Crider, 2008). According to the *effortful control hypothesis*, people with high EDR lability invest greater cognitive effort to inhibit their expression (Crider, 2008; Carver, 2005; Nigg, 2003). The effortful control differs from the behavioral inhibition, which is a more automated and less reflective kind of inhibition and which is triggered by the approach-avoidance motivation (Fowles, 2000; Gray & McNaughton, 2000). Murray and Kochanska (2002) have defined effortful control as an ability to inhibit a dominant response and to initiate a subdominant response which is consistent with situational requirements.

The effortful control hypothesis derives from Öhman's information processing approach to the EDR component of the orienting response. In Öhman's analysis, specific EDR is seen as a peripheral manifestation of neural activation, driven by demands on cognitive capacity (Crider, 2008; Murray & Kochanski, 2002). Specific EDR seems to reflect a requirement for resources when the current capacity is insufficient to meet the needs for immediate processing. Studies show that phasic electrodermal activity is sensitive to demanding tasks, electrodermally labiles showing less capacity available in the face of cognitive tasks. The demand for resources that is signaled by EDR activity may not be satisfied if a limited cognitive capacity is currently allocated to competitive and cognitively demanding tasks. Therefore, the relationship between EDR activity and processing efficiency varies according to the degree of concurrent competition for a limited processing capacity (Crider, 2008; Öhman, 1979; Öhman et al., 2000).

4. Cybernetic approaches in psychological theories

In recent years, interdependent models of the main personality traits have gained ground. An *interdependent system for the adaptation of personality* focuses on the interactions between main personality traits, as a response to internal and external stimuli (inputs), such as stressors or feedback (Bogg & Vo, 2014; Van Egeren, 2009). These interdependent models partially use the cybernetic feedback control theory (Wiener, 1948). The cybernetic theory describes how a mechanism exerts control over its own functioning, as a response to inputs, in order to achieve its self-regulation goals. This model, correlated with an adaptation system of personality, can describe independent and interdependent functioning of trait groups in order to facilitate goal-oriented actions.

The central idea of cybernetic models is that the unmet part of the goals (e.g. the remaining part of the way to the point X) is the engine of all self-regulated actions (Wiener, 1948). From a *cybernetic perspective,* the purpose of the adaptive response in a system of personality (whether it is independent or interdependent) is to support the carrying out of goal-oriented actions (e.g. maintaining physical health). From an *interdependent perspective*, different levels of traits, as well as different levels of different combinations of traits may correspond to different levels of the same responses, or even divergent responses (Bogg & Vo, 2014). Van Egeren (2009) argues on the inability of 'Big Five' model to explain how personality traits work interdependently to exert control over human behavior. A first task of the personality theory is to describe this process of control. In the *cybernetic model* proposed by Van Egeren, the author looks for parallels between basic commands that operate in cybernetic self-regulatory systems and the Big Five personality traits. The cybernetic feedback control theory (Powers, 1973a,b; Wiener, 1948) specifies the minimal set of commands that self-regulatory systems (e.g. a space heating system) require to meet a preset goal.

The theory provides a useful metaphor for how personality traits exert control over behavior. Human beings differ greatly in how they control their actions (some impulsively, others prudently etc.). The way they do this gives each individual the distinct characteristics that can be composed into an integrating theory of personality. According to Van Egeren's hypothesis (2009), human beings *mentally incorporate control propensities of actions in global personality traits*, these traits being responsible for encoding all major types of control necessary to achieve a goal. There are two types of scientific data available for assessing the strength of the relationship between personality traits and self-regulation processes of control. The first is descriptive in nature and it is included in the definition of trait construct. The descriptive terms that compose a trait and its functioning pattern can indicate, by themselves, specific self-regulatory operations that function through that trait. The second type of data is based on human and animal temperament research that relates personality traits with behavioral processes and brain mechanisms (Van Egeren, 2009; Depue & Collins, 1999; Gray, 1991; Watson & Clark, 1992).

The *temperament theory* and its underlying research have had a strong impact in the investigation of neurobehavioral regulatory mechanisms, by associating personality traits with human behavior (Van Egeren, 2009). For example, extraversion has been empirically associated with motivational reactivity to rewards (Depue & Collins, 1999), neuroticism with strong reactivity to punishments (Gray, 1987; Watson & Clark, 1984), and conscientiousness with the regulation of these two reactive trends (Rothbart, Ahadi, & Evans, 2000). From a temperamental view, any adaptation of an organism to its environment, its very survival, depends on the way it approaches rewards and avoids punishments (Schneirla, 1959).

The theory of human agency (Bandura, 2006) differs significantly from temperament theory and is more consistent with the cybernetic control model. This perspective assumes that human responsiveness to external stimuli has an active component, according to personal needs and goals (Carver & Scheier, 1990; Emmons, 1995; Little, 1989; Pervin, 1983).

Van Egeren applies a psychological form of the cybernetic model of control (Table 1) to reinterpret personality traits or temperament types as predispositions to adjust goal oriented actions in particular ways, specific to the individual. Thus, *personality traits are associated with self-regulatory controls that underlie behavioral patterns, rather than manifest behavioral patterns themselves* (Van Egeren, 2009).

Table 1

Control Domain	***Perspective***	***Description***
Goal – behavior	Temperamental Agency Cybernetic Trait	Disposition to respond to rewards Disposition to actively pursue goals Behavioral output Extraversion
Behavior – situation	Temperamental Agency Cybernetic Trait	Disposition to constrain dominant response Disposition to adapt behavior to the situation Output impact on controlled quantity in the environment Conscientiousness
Situation – outcome	Temperamental Agency Cybernetic Trait	Disposition to attend to environmental objects Disposition to anticipate outcomes Feedback of controlled quantity state information Openness to Experience
Outcome – goal	Temperamental Agency Cybernetic Trait	Disposition to respond to threats Disposition to emotionally respond to failures Error detection Neuroticism
Person – person	Temperamental Agency Cybernetic Trait	Disposition to make social contact; affiliation Disposition to form cooperative social relationships Interlinked feedback loops Agreeableness

*reproduced from Van Egeren, 2009

5. Psychophysiological inference

The methodology of psychophysiological inference progressively clarifies the validity context of correspondences between physiological and psychological aspects, and the engineering process of implementation, whatever it may be, must be correctly related to the validity classes of inferential relationship. In support of such experimental initiatives, Cacioppo and Tassinary (1990) addressed the inference of psychological significance from physiological signals, arguing on the inconsistency of research results regarding correlations that can be found between physiological and psychological events. Reviewing a number of obstacles that arise in psychophysiological inference, the two authors place the debate in a plane that systematizes relationship types between physiological (Φ) and psychological (Ψ) events. Therefore, they reveal aspects of specificity and generality of elements included in the correlation, taking into account the dynamic of inference that polarizes four quadrants of the plane, appropriately describing the outcomes, concomitants, invariants and markers specific for each type of inference (Fig.1).

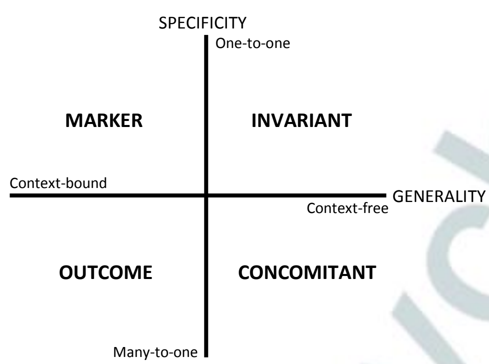

Fig.1
Major dimensions and classes of psychophysiological relationships
**reproduced from Cacioppo & Tassinary, 1990*

The two authors believe that psychophysiological inference may be distorted by inadequate technical knowledge of working tools and limitations of new technologies, and this can lead to serious errors of inference. Also, we could infer from this that physiological signals would have little to do with psychological processes or behavior (simply because insufficient technical considerations are collected before the interpretation of physiological signals), although this would be a serious obstacle in the inferential technique. The authors also report cases where there may be differences between measurement results on the same phenomenon, but through different processes (e.g. electrodermal activity assessed by measuring resistance or conductance)[2].

Uncertain psychophysiological aspects can also result from the impreciseness of signal acquisition time on the psychological side of the equation. Also, the authors take into account the fact that progress in comprehensive representation and complex analysis of physiological signals have lagged behind advances in signal acquisition. Another major error in the inferential technique is derived from particular representations that specifically make some information explicit over other information and, therefore, make some operations or insights more simple, and others more difficult (for example, information about the size of a signal are understood by representing the amplitude of a physiological response, while information about the possible periodicity of a signal are made explicit by the frequency of a physiological response).

Transforming this complexity of situations into an advantage, it was discovered that the number of complex relationships of normality (e.g. many-to-many), the relationships between physiological and psychological phenomena, may be specified in more simple forms, much more interpretable in restrictive evaluative contexts. Thus, when considering configural and temporal forms of type Φ and type Ψ, psychophysiological relationships can be found useful in terms of their specificity and generality[3].

Cacioppo and Tassinary place the entire assembly of causal relationships between physiological and psychological elements in a frame of orthogonal dimensions, setting out for each of the four quadrants, a class of psychophysiological relationship and the nature of inferences that they allow.

The outcome, as a first class of relationships, is ideally defined as a *many-to-one* relationship, the specific or individual situation between Φ or Ψ (or, equivalently, Φ' or Ψ'). Establishing that a physiological event varies as a function of a psychological operation, it is suggested that the psychophysiological relationship is an outcome. This is the first relationship to be established in psychophysiological studies taking into account that:

a) the physiological event covaries with changes in the psychological event, depending on the circumstances and individuals;

b) the physiological response only covaries with changes in the psychological event;

c) the properties of generality or specificity may be achieved by redefining the physiological events (e.g. Φ' or Φ'') or the psychological elements (e.g. Ψ' or Ψ'');
Following this procedure, a given psychophysiological relationship may be initially classified as an *outcome*, but subsequently reclassified as:

[2] In recent decades, psychophysiological research has shown that measurements of skin resistance response are strongly influenced by irrelevant characteristics for allegedly measured changes in physiological activity. For example, sweat gland activity levels can significantly influence the size of the electrodermal response to an experimental stimulus, when the response is measured rather in resistance than conductance; the measurements of skin resistance response covariate in a much less linear fashion with actual changes in underlying physiological activity (e.g. the number of active sweat glands in a region, or their rate of secretion), than the measurement of skin conductance response; usually, measurements of skin resistance response are less distributed than measurements of skin conductance response;

[3] Specificity (e.g. one-on-one compared to many-to-one) and generality (e.g. situation or person specific compared to cross-situational).

- a *marker*[4], once the property of specificity is established in at least one limited evaluative context;
- a *concomitance*[5], once the property of generality is demonstrated;
- an *invariant*[6], once both properties of specificity and generality have been established.

It is important to note that this procedure does not cause erroneous inferences. Any strong inference predicted as a resulting relationship requires a *marker*, a *concomitance*, or *invariant* psychophysiological relationships, also for inferences based on hypothetical-deductive logic:

- it is the only strong considered form when dealing with a resulting relationship (or only when a resulting relationship has been documented in this manner so far);

- it is guided more by the absence than presence of empirical evidence for a hypothesis (when two theoretical models differ in their prediction on one or more physiological responses, the empirical support fails to grow at least for one of these competing hypotheses; therefore the logic of experimental design allows theoretical inferences to be developed based on physiological signals - especially in the absence of predicted physiological signals).

An implication of those above suggests that the strong inferences about psychological significance of physiological events are necessarily guided by hypothetical-deductive logic when dealing with *many-to-one* type of psychophysiological relationships (e.g. outcomes, concomitance), and can be guided by hypothetical-deductive logic when dealing with *one-to-one* type of psychophysiological relationships.

Also, when a physiological event differentiates between the presence and absence of a specific psychological element, the absence of this psychological element may be inferred due to the unoccurence of the physiological event, but nothing can be inferred about the presence of psychological element due to the occurence of a physiological event. Thus, the psychophysiological correlations can be valuable in disapproving theoretical predictions, but are insufficient if the goal is to reach an index of an element in the psychological field. This warning is often brought up in discussions related to the scientific method and is probably violated just as often in scientific practice (Cacioppo & Tassinary, 1990).

Therefore, we can see that psychophysiological assessments were often implemented for testing causal hypotheses about the role of physiological events or for calibrating the presence or the expansion of a particular psychological event or process. However, unless the psychophysiological relationship is *invariant*, or two or more theories make competitive predictions related to the physiological response, the knowledge about the effects of changes in psychological / behavioral variables does not provide enough information for a strong inference about the psychological variable considering the physiological response.

6. Electrodermal potential in alternating current (AC)

According to Edelberg's exocrine model, one of the most widely accepted theoretical models of skin conductance, the phasic changes of skin conductance occur when the skin glands fill, and the skin conductance returns to baseline when this moisture is reabsorbed in the glands. In this model, in fact, the exocrine glands are seen as resistors. The conductance increases (the resistance decreases) when these glands are filled. The amplitude of conductance modification derives from the amount of solution contained in the glands, but also from the number of exocrine glands that are simultaneously activated. The activation of exocrine glands is neurally regulated, being controlled by the brainstem. This is part of the phenomenology of exodermal manifestations of the brain, the electrodermal activity being a projection of the activity of reticular formation of the brainstem, the hypothalamus, the limbic system and the motor cortex (Bloch et al., 2006). It is also known that the electrical activity of the skin is linked with the blood flow in the peripheral areas, depending directly on the heart rate.

It is known, however, that in the case of conductive media, the charge carriers can be electrons (in metals) or free ions in suspension (in solution), in the case of biological tissues. When a DC passes through an ionized solution, the phenomenon of polarization occurs, which can cause tissue heating or, in extreme cases, tissue destruction. Gildemeister (1920) was among the first to overcome this drawback by using an alternating current (AC) and measuring the total opposition to its passage through a tissue (Lawler, Davis, & Griffith, 1960). In his research on brain electrical activity between the years 1955-1960, A. L. Thomasset used AC instead of DC, considering that the body is an ionic and inhomogenous conductor (Thomasset, 1962, 2002). In this case, the manifest characteristic that is connected to the physiological activity of the tissue being subjected to an AC is the ***impedance***. The measurement of impedance (Z) on a biological tissue involves both the

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[4] The *markers* represent the fundamental relationship between psychological and physiological elements that allow an inference to be drawn on the measurement of the former, based on measuring the latter. The main requirements for establishing that a relationship between a physiological and a psychological event qualifies as a marker are:
- Demonstrating that the presence of the physiological element accurately predicts the psychological element;
- Demonstrating that the physiological element is insensitive (e.g. uncorrelated) to variations in other psychological elements or factors in the assessment context;
- Specifying conditions to limit the validity of the two preceding conditions;

[5] A psychophysiological *concomittance* is defined as a *many-to-one* association between the abstract events Φ and Ψ, that can be generalized to situations and individuals. It only refers to the conditions and implications of covariance and does not discriminate between instances in which psychological operations cause physiological events (or vice versa), when there are reciprocal influences, or when the third variable is responsible for their covariance.

[6] An ideal *invariant* relationship refers to a general isomorphic association (*one-to-one)* of the type:
a) a particular element in Φ is present only when a specific element in Ψ is present.
b) the element in Ψ is present if and only if the corresponding element in Φ is present.

electrical resistance of the tissue (R) and its capacitive reactance (Xc), according to the formula $Z^2 = R^2 + Xc^2$. Physically, the resistance is the opposition of a conductor to an AC, being essentially the same in biological tissues as in nonbiological conductive materials (Kay, Bothwell, & Foltz, 1954; Nyboer, 1959), while the capacitive reactance of a biological tissue is caused by the additional oposition to an AC through the capacitive (storing) effect of bilipid cell membranes, of tissue interfaces and of structural characteristics (Baker, 1989; Barnett & Bagno, 1936; Schwan & Kay, 1956, apud. Chumlea & Guo, 1997). The membranes act as a dielectric or insulator that separates the extracellular and intracellular fluid, behaving like valves of the biological capacitor. Even in the case of AC, epidermal humidity is a determinant factor for penetration into the body. It is worth noting that low frequencies below 5.000 Hz are conveyed only through the connective tissue of the body (Ivorra & Aguiló, 2001; Ivorra & Rubinsky, 2007), while higher frequencies penetrate the outer layers of the cell (in referring to sinusoidal signals, using rectangular signals creates higher frequency harmonics that can enter the cell, even if the base frequency is low).

Authors like Boucsein, Schaefer, and Neijenhuis (1989) argue that exosomatic electrodermal recording techniques primarily focus on the tonic measurement, rather than phasic measurement. However, the measuring methods for phasic AC are the most useful in testing electric models of electrodermal response. For this, concepts of appropriate measurement are being developed for continuous recording of the impedance and phase angle (the second measurement that characterizes physiological parameters, besides impedance) (Chumlea & Guo, 1997; Baumgartner, Chumlea, & Roche, 1988; Lukaski & Bolonchuk, 1987; Subramanyan et al., 1980). The phase angle is expressed in degrees, as the arctangent of the ratio Xc/R, depending on the frequency of the current used.

In addition, the literature records the existence of two different types of "*human electrical impedance*" (Sutherland, Dorr, & Gomatom, 2005), namely an impedance of the surface (of the skin), and an internal impedance (of the whole body), which is basically resistive. The epidermal surface layer, that contains dead cells deposited on a living, heterogeneous and non-isotropic layer, shows both resistance and capacitance (Sălceanu, Iacobescu, & Anghel, 2013). The capacitive impedance decreases with frequency at higher resistances. According to some authors (Fowles et al., 1981), a drawback of using AC in electrodermal measurements is that capacitive properties of the skin are added to conductance values, resulting in too high conductance values. Since, as we previously mentioned, the skin capacitance is directly proportional to the frequency of measurement, by using a low frequency, below 40 Hz, with a phasic-sensitive correction, the skin capacitance may become negligible. The cited authors have experimentally demonstrated that the *electrodermal potential* is a stronger parameter than conductance, being much less dependent on the constancy of skin contact area with the electrode, which causes the artifacts to be more pronounced in skin conductance curves than in potential curves. The method that Fowles used in 1981 requires a DC and cannot separate conductance and electrodermal potential waveforms. In order to study the electrodermal generating mechanisms, the electrodermal potential must be measured without the DC and compared with the conductance results in AC. This is possible by phasic-sensitive correction, by real time signal processing and by variable conversion (Grimnes, Jabbari, Martinsen, & Tronstad, 2011).

The advantages of using the DC conductance are supported by the simple fact that there is no skin capacitance there, and by a large number of references that exist in the literature. The disadvantages may include: the limit of 50mA/cm2, the intervention by changing the electromotive force that is generated in the circuit on the electrodes and in the skin (electro-osmosis, the filling of the sweat channels, the membrane potentials, the electrolysis of the skin and the irritation), the use of bipolar electrodes, that involves data coming from two different places of the skin, with unequal measurement areas, which is why conductance in DC is not suitable for physiological research (Grimnes et al., 2011). Although the measurement system in AC is far more complicated, requiring a greater number of parameters to follow, AC conductance however, enables measurement of electrodermal potentials, simultaneously, in the same place on the skin. Also, the absence of DC power leads to less stringent requirements for the electrode technique, so the monitoring of their potential error or polarization during use becomes unnecessary. Lastly, the sensors do not irritate the skin as in DC, and AC conductance is not affected by changes of electromotive force. Therefore, the electrodermal potential becomes a valuable indicator of autonomous and somatomotor aspects of cognitive functioning, of emotion, motivation and attention. It is manifest in the absence of DC, with the possibility of collecting (by using unipolar sensors) these following two aspects: the skin potential level (SPL) and the skin potential response (SPR).

7. Neurostimulation of phasic response of the electrodermal potential in AC

The studies conducted with MindMi™ System on phasic electrodermal neurostimulation (Grigore, 2013), on athlete performance monitoring (Grigore et al., 2013), and on wakefulness monitoring through direct electrodermal measurements (Grigore et al., 2014) have confirmed the hypothesis that simultaneous stimulation of the phasic response with a step signal and an alternating voltage signal accurately highlights the degree of electrodermal lability and stability, respectively, as well as the skin potential response in AC. The shape of the excitation step signal is given by:

$$u_1(t) = \sum_{k=1}^{N} A_k \left[\sigma(t - kT) - \sigma(t - (k+1)T)\right]$$

where $\sigma(x - x_0) = 1$; $x \geq x_0$; $\sigma(x - x_0) = 0$; $x \leq x_0$ is the Heaviside function, A is the amplitude of the step signal and T is the period of this signal.

The alternating voltage signal is generated according to the degree of electrodermal lability, its frequency and amplitude being controlled by computer based software assistance:

$u_2(t) = A_S \cos\left(\frac{2\pi t}{T_0}\right)$, where A_S is the controllable amplitude of the signal, and T_0 is its period, determined by frequency control.

Composing the excitation step signal and the alternating voltage signal on the skin surface results in a signal that has the following form:

$$u_{Total}(t) = A_S \cos\left(\frac{2\pi t}{T_0}\right) + A_t \sum_{k=1}^{N} k\left[\sigma(t-3kT) - \sigma(t-3(k+1)T)\right]$$

This will be correlated with the phasic response of skin potential in AC.

The third variable is the $\lambda(t)$ function, the expression in time of the electrodermal lability. Its value serves as an input parameter for the control loop of the frequency and amplitude of the alternating excitation signal. Its evolution over time is related to the density of SPR recorded in a cycle of measurement[7], thus showing a high lability in case of a high density, and a low lability in case of a low density, respectively.

The neurostimulation of phasic response of the electrodermal potential in AC is therefore a process that involves the electrical stimulation of the skin and its maintainance in an excited state, in a time frame calibrated at the level of phasic conductance (Grigore, 2014). For this, an excitation step signal and an alternative one are used. These signals are controlled in frequency and amplitude depending on the SPR density captured on a measuring cycle. As a result of this stimulation, according to the principle of self-regulation through inverse connection between system outputs and sensory inputs, the *skin potential response* in AC is in projective correspondence with bioelectrical events occurring in the body, that result in self-regulation processes where the psychophysiological functions manifests.

8. Psychophysiological variables in the cybernetic model of MindMi™ System

Performing the cybernetic modeling of personality traits, temperament types, and propensities to regulate goal-oriented actions, and approaching the input variables related to electrodermal activity, the MindMi™ System identified emotional and cognitive measurable dimensions that can be determined by behavioral inhibition or activation, depending on the electrodermal response and its lability. Thus, according to the theories presented above, we considered the association of *EDR lability* (through $\lambda(t)$ function, which is perfectly determinable by direct measurement, as the density of the skin potential response to a stimulation cycle) with the *regulatory function of AC excitation* (by controlling the frequency and amplitude of the signal), in order to determine the level of *psychophysiological activity*, by linking skin potential response with the degree of inference of this activity in each area of measurement.

To complete the algorithm that implements the new cibernetic model, the following aspects were considered, which were previously described:

- *the electrodermal activity increases* when the *behavioral inhibition system is activated;*
- *an increased EDR lability* is associated with an *undemonstrative and agreeable disposition*; a *high EDR stability* is associated with an *expressive and antagonistic disposition* (Crider, 2008; Fowles, 1980);
- *overcontrolled* people are described as emotionally undemonstrative, shy and agreeable, while *undercontrolled* people are described as expressive and antagonistic (Robins et al., 1996);
- when behavioral expression is blocked due to social pressure or other reasons, emotional impulses can be expressed by a high sympathetic activation (Jones, 1950); *electrodermal lability can be interpreted as an internalized way of emotional expression when the externalized expression is inhibited;*
- the electrodermal lability can act as a *psychophysiological marker* for individual differences in the effortful control of emotional expression and antagonistic behavior (Crider, 2008). *Corelating this with the skin potential response in AC (limited evaluative context) proves specificity and generality, transforming this marker from a concomitance into an invariant*, which meets the condition for a strong inference (Cacioppo & Tassinary, 1990);
- according to the *effortful control hypothesis*, people with high EDR lability invest greater cognitive effort to inhibit their expression (Crider, 2008; Carver, 2005; Nigg, 2003).
- the effortful control hypothesis derives from Öhman's information processing approach to the EDR component of the orienting response: *specific EDR is seen as a peripheral manifestation of neural activation, driven by demands on cognitive capacity (*Crider, 2008; Murray & Kochanski, 2002);
- specific EDR seems to reflect a requirement for resources when the current capacity is insufficient to meet the needs for immediate processing;
- electrodermally labile people are showing less capacity available in the face of cognitive tasks;
- the relationship between EDR activity and processing efficiency varies according to the degree of concurrent competition for a limited processing capacity (Öhman, 1979; Öhman et al., 2000);
- *empirical associations between personality and behavior can be derived from individual differences in brain functioning parameters* (Matthews & Gilliland, 1999);
- the level of *arousal* (physiological activation) can be related to a scale of introversion - extraversion (Eysenck) in order to describe individual personality types and their corresponding behavioral patterns;
- extraversion has been empirically associated with motivational reactivity to rewards (Depue & Collins, 1999);

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[7] A measuring cycle refers to the total time that takes the excitation signal to pass through all areas of measurement. MindMi™ System responds to 45 of such cycles.

- neuroticism has been empirically associated with strong reactivity to punishments (Gray, 1987; Watson & Clark, 1984), and conscientiousness with the regulation of these two reactive trends (Rothbart, Ahadi, & Evans, 2000);
- the *behavioral inhibition system* (Gray, 1982, 1985a,b) has its neural bases in the septal area of the limbic system and in the hippocampus (the septo-hippocampal system and its interconnected structures);
- the behavioral inhibition system is a neuropsychological system related to sensitivity to punishment and aversive (avoidance-related) motivation, which inhibits motor behavior (Fowles, 1980);
- the *behavioral activation system* corresponds to sensitivity to rewards and appetitive (approach-related) motivation, being related to the individual's disposition of pursuing and achieving his goals;
- multiple interactions have been found between main personality traits, as a response to internal and external stimuli (inputs), such as stressors or feedback (Bogg & Vo, 2014; Van Egeren, 2009);
- the *cybernetic theory* (Wiener, 1948) describes how a mechanism exerts control over its own functioning, as a response to inputs, in order to achieve its self-regulation goals. The central idea of cybernetic models is that the unmet part of the goals (e.g. the remaining part of the way to the point X) is the engine of all self-regulated actions (Wiener, 1948);
- a cybernetic model, correlated with an adaptation system of personality, can describe independent and interdependent functioning of trait groups in order to facilitate goal-oriented actions;
- from a *cybernetic perspective,* the purpose of the adaptive response in a system of personality (whether it is independent or interdependent) is to support the carrying out of goal-oriented actions;
- from an *interdependent perspective*, different levels of traits, as well as different levels of different combinations of traits may correspond to different levels of the same responses, or even divergent responses (Bogg & Vo, 2014);
- the *cybernetic feedback control theory* (Powers, 1973a,b; Wiener, 1948) specifies the minimal set of commands that self-regulatory systems (e.g. a space heating system) require to meet a preset goal, providing a useful metaphor for how personality traits exert control over behavior;
- human beings differ greatly in how they control their actions (some impulsively, others prudently etc.). The way they do this gives each individual distinct characteristics that can be composed into an integrating theory of personality;
- according to Van Egeren's hypothesis (2009), *human beings mentally incorporate control propensities of actions in global personality traits*, these traits being responsible for encoding all major types of control necessary to achieve a goal;
- the descriptive terms that compose a trait and its functioning pattern can indicate, by themselves, specific self-regulatory operations that function through that trait;
- from a temperamental view (*the temperament theory*) any adaptation of an organism to its environment, its very survival, depends on the way it approaches rewards and avoids punishments (Schneirla, 1959);
- *the theory of human agency* (Bandura, 2006) assumes that human responsiveness to external stimuli has an active component, according to personal needs and goals, that are followed actively and proactively rather than reactively (Carver & Scheier, 1990; Emmons, 1995; Little, 1989; Pervin, 1983);
- *personality traits are associated with self-regulatory controls that underlie behavioral patterns, rather than manifest behavioral patterns themselves* (Van Egeren, 2009);
- there is a set of four functions, named here "behavioral functions", which regard the understanding, organization (in terms of control of actions), decision and networking. These have antagonistic nominal values and by combining them, a number of behavioral types can be linearly identified (Grigore et al., 2013).

According to the *effortful control hypothesis*, people with high EDR lability invest greater cognitive effort to inhibit their expression (Crider, 2008; Carver, 2005; Nigg, 2003). The effortful control hypothesis derives from Öhman's information processing approach to the EDR component of the orienting response: *specific EDR is seen as a peripheral manifestation of neural activation, driven by demands on cognitive capacity (*Crider, 2008; Murray & Kochanski, 2002).

The algorithm developed based on the above mentioned criteria subjects the acquisition data (collected from the palm surface of the hands) to a sequence of preliminary processing, in order to identify the *neurophysiological activity level (*$\boldsymbol{C_x}$*) in each area of measurement. This is associated with the skin potential response (SPR) obtained by neurostimulation AC, and with the level of inference*[8] *(*$\boldsymbol{F_y}$*) of the neurophysiological activity in psychological aspects, which corresponds to each area of measurement correlated with the degree of electrodermal stability.* The value of several indicators ($\mathbf{I_{pxy}}$) with psychological significance is further calculated. These reflect *the neurophysiological activity and the corresponding inference in each area of measurement, expressing the activity level of cognitive, affective or volitional functions* they projectively represent. Using these indicators of psychological significance, a programmable platform is provided, where the user can customize, in a user-interface, any other psychological construct, in addition to the predetermined ones.

9. Conclusions and Implications

After a continuous process of modelling, developing and refinement of the MindMi™ patented system, which we partially described in this material, a number of psychological traits and indicators have become measurable through a non-invasive hand scanning device, using the

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[8]Inference is the degree to which a neurophysiological activity can express one or more psychological aspects.

active principle of sweat gland activity as a peripheral manifestation of neural activation.

The device measures biopotentials from the skin surface (skin potential response and skin potential level) through a dual hand scanner with monopolar electrodes that gather all the necessary data in 5 minutes. After the scan, the system uses the collected data to acquire psychological information through an innovative algorithmic procedure. The algorithm combines multiple variables of key relevance for their corresponding personality traits (e.g. the amplitude, the lability of the electrodermal response, the level of cortical arousal, and others). This core set of variables goes through a *cybernetic modelling* process, resulting in a numerous set of psychological indicators that reflect cognitive, emotional and social abilities, but also specific aptitudes and tendencies. The psychological indicators obtained are further used to create extensive psychological reports that comprise information about an examinee's personality, cognitive intelligence, emotional intelligence, cognitive pattern, and interpersonal or group compatibility.

These results can be used as an extensive source of information, having a key relevance for psychological assessment processes. The reports provided by the MindMi™ System, along with results from other assessment tools, thus become pieces of a puzzle that a specialist is assembling on behalf of the examinee.

MindMi™ facilitates more comprehensive data gathering and it can act as a decision support technology. It is important to note that MindMi™ reports do not treat or diagnose, but the information obtained with the system can be successfully integrated with other sources (e.g. interview, other psychological tests, practical activities or assessment centers).

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