

EPISTEMOLOGICAL PERSPECTIVES IN THE SCIENTIFIC STUDY AND EVALUATION OF EXECUTIVE FUNCTION

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Abstract

In this article, epistemological perspectives that have shaped and affected the scientific quest for understanding what neuropsychologists term “executive functions” are reviewed. Executive functions refer to the control functions of cognition and behavior. The underlying thesis of the paper is that one’s epistemological orientation determines how one sees the interaction between brain functions and our status in the world. Each different orientation thus carries with it implications with regard to how executive functions operate, as well as how, therefore, one should try to assess them. Until recently, these functions were approached through two primary epistemological points of view. One is analytic, which has its roots in the positivistic movement. The other approach is synthetic, otherwise known as “romantic science”, and forms the basis of the work of the prominent Russian neuropsychologist A.R. Luria. A third epistemological perspective, articulated under the umbrella of ‘embodied cognition’ approaches, has been advanced in the last 20 years, and is associated most closely with the work of Francisco Varela. A review of, and reflection on how these perspectives have affected research and clinical practice in neuropsychology is provided.

Key words: Executive functions, neurophenomenology, neuropsychology, embodied cognition, epistemology, classical science, romantic science, clinical evaluation.

PERSPECTIVAS EPISTEMOLÓGICAS EN EL ESTUDIO CIENTÍFICO Y LA EVALUACIÓN CLÍNICA DE LAS FUNCIONES EJECUTIVAS

Resumen

En este artículo se examinan perspectivas epistemológicas que han moldeado e influenciado la búsqueda científica orientada hacia comprender aquello que los neuropsicólogos denominan las “funciones ejecutivas (FE). El término funciones ejecutivas se refiere a aspectos de control de la cognición y la conducta. Las ideas expuestas en este manuscrito presuponen que la orientación epistemológica de una persona determina la manera en la que ella conceptualiza la interacción entre las funciones cerebrales y su entorno físico. Cada una de esas orientaciones conlleva suposiciones acerca del modo como operan las FE y, por ende, el modo como deben ser evaluadas. Hasta fechas recientes esto se había abordado principalmente desde el punto de vista de dos perspectivas teóricas. Una de ellas, la analítica, tiene sus raíces en el movimiento positivista. La otra, también conocida como “ciencia romántica” es sintética, y provee las bases del trabajo científico del muy celebrado neuropsicólogo ruso A.R. Luria. Una tercera perspectiva, formulada en el marco de la “cognición corpórea”, ha sido propuesta en los últimos 20 años, y está más estrechamente asociada con los trabajos de Francisco Varela. Se examina aquí, por medio de una revisión reflexiva e integradora de la literatura pertinente, la manera como esas tres perspectivas epistemológicas han influido sobre la investigación y la práctica clínica de la neuropsicología.

Palabras clave: Funciones ejecutivas, neurofenomenología, neuropsicología, cognición corpórea, epistemología, ciencia clásica, ciencia romántica, evaluación clínica.

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PERSPECTIVAS EPISTEMOLÓGICAS NO ESTUDO CIENTÍFICO E A AVALIAÇÃO CLÍNICA DAS FUNÇÕES EXECUTIVAS.

Resumo

Neste artigo examinam-se as perspectivas epistemológicas que moldaram e influenciaram a busca científica orientada à compreender aquilo que os neuropsicólogos denominam as “funções executivas (FE). O termo funções executivas se refere a aspectos de controle da cognição e a conduta. As ideias expostas neste manuscrito pressupõem que a orientação epistemológica de uma pessoa determina a maneira em que ela conceitualiza a interação entre as funções cerebrais e seu entorno físico. Cada uma dessas orientações leva a suposições sobre o modo como operam as FE e, portanto, o modo como devem ser avaliadas. Até datas recentes isto havia sido abordado principalmente desde o ponto de vista de duas perspectivas teóricas. Uma delas, a analítica, tem suas raízes no movimento positivista. A outra, também conhecida como “ciência romântica” é sintética, e fornece as bases do trabalho científico do muito celebrado neuropsicólogo russo A.R. Luria. Uma terceira perspectiva, formulada no marco da “cognição corpórea”, foi proposta nos últimos 20 anos, e está mais estreitamente associada com os trabalhos de Francisco Varela. Examina-se aqui, através de uma revisão reflexiva e integradora da literatura pertinente, a maneira como essas três perspectivas epistemológicas influíram sobre a pesquisa e a prática da neuropsicologia.

Palavras chave: Funções executivas, neurofenomenologia, neuropsicologia, cognição corpórea, epistemologia, ciência clássica, ciência romântica, avaliação clínica.

INTRODUCTION

Executive functions (EFs) are central to the performance of complex acts and play a role in all higher cognitive processes. They include the ability to plan, sequence, initiate and organize actions, set priorities, use feedback to guide behavior, maintain focus in the face of distraction, switch strategies, and inhibit responses as needed. In children, their impact on learning and self-regulation is critical, as is their contribution to the acquisition of, and adherence to, social norms. Executive dysfunction is common to a number of disorders that affect the nervous system, and the identification of executive dysfunction is important in allowing treatment to be better focused. Yet the field, despite having made significant strides in unraveling many aspects of executive function, is still not close to providing a cohesive, integrated view that fully encompasses its complexities. However, the way in which EFs are assessed and studied is a product of one’s epistemological point of view, since EFs are control functions that determine how we interact with the world. That is, how one conceptualizes the factors involved in the way humans adapt to the world will inform and define the way EFs, which are the control functions of the brain, are conceptualized, studied and assessed.

In this article we review the epistemological perspectives that have guided most research in science, and, more specifically, neuroscience, including the investigation of EFs. This may help to understand differences in approaches to the assessment of EFs that can be found in the field of neuropsychology. Furthermore, the relatively recent appearance of a new epistemological perspective has implications for assessment that challenge the field to develop

methodologies that can more accurately reflect individual differences in a more holistic way.

Two approaches have historically characterized how scientists have tackled the investigation of executive functions: one synthetic, the other analytic (also referred to as the ‘classical perspective’). They have their roots in two disparate philosophical traditions: the first, known as ‘romantic science’, is a holistic perspective, which became the dominant epistemological force from the mid to the late 1800’s; the latter is the positivist movement (also referred to as the ‘classical perspective’) that flourished in Austria in the early 1900s.

A third perspective, while still challenging neuropsychologists to formulate a viable clinical methodology for the assessment of EFs, provides a conceptual bridge between the phenomenology of experience and constraints imposed by human physiological functioning (Varela, 1996).

The positivistic epistemological approach

Proponents of the analytic perspective had their stronghold in Vienna. An impressive cadre of scientists spurred the movement that created a science of logic and cold facts. Mach is credited with having provided the initial impetus for what would culminate in the Circle of Vienna, a powerful force whose influence spread in Europe, later to shape the scientific enterprise in North America (2004). Its guiding principles are stated in a Manifesto drafted in the 1920s, and leave no doubts about the views of its followers. Entitled *Wissenschaftliche Weltauffassung der Wiener Kreis* (The Scientific Conception of the World: The Vienna Circle), its authorship is uncertain, but it is assumed to have been a collaborative effort (Murzi, 2005). The following are quotes from the document [our emphasis]:

“In science there are no ‘depths’; there is surface everywhere: all experience forms a complex network, which cannot always be surveyed, and can often be grasped only *in parts*.... The judgments of arithmetic, geometry, and certain fundamental principles of physics, that Kant took as examples of *a priori* knowledge will be discussed later.... It is precisely in the *rejection of the possibility of synthetic knowledge a priori* that the basic thesis of modern empiricism lies. The scientific world-conception knows only empirical statements about things of all kinds, and analytic statements of logic and mathematics. We have characterized the *scientific world-conception* essentially by *two features*. *First* it is *empiricist and positivist*: there is knowledge only from experience, which rests on what is immediately given. This sets the limits for the content of legitimate science. *Second*, the scientific world-conception is marked by application of a certain method, namely *logical analysis*. The aim of scientific effort is to reach the goal, unified science, by applying logical analysis to the empirical material” (*Wissenschaftliche Weltauffassung der Wiener Kreis*).

Wundt is reputed to have founded experimental psychology along these premises (Boring, 1950). Inspired by the successes of physiologist Gustav Fechner in studying sensory perception by manipulating stimuli and having subjects report back their experience, Wundt sought to emulate researchers in the natural sciences who, through careful measurement of observable phenomena, were making inroads towards identifying and understanding the building blocks (atoms) of matter and living organisms. As for other aspects of the human experience, he felt they were not the proper subject of scientific psychology, but the province of the “humanities” such as art, literature, and anthropology, which he termed *Volkerpsychologie* (Guski-Leinwand, 2009; Wong, 2009).

As the historic turn of events would have it, positivism flourished in North America, largely as a consequence of the exodus from Austria and Germany of many intellectuals in the “Enlightenment” tradition, and their relocation in the “New World”. In psychology, Titchner, a disciple of Wundt, introduced structuralism to America. This approach sought to identify the most basic elements or components of the mind based on introspection, and then study their connections to determine an overall mental structure and conscious experience.

In the United States, a seminal publication by William James (1890) greatly influenced the way this discipline was to be approached in the decades to follow. This two-tome opus, *Principles of Psychology* (1890), caused James’ name to become most readily associated with Pragmatism, an

approach to science which, in principle, aligns itself with the scientific method pursued by positivists. Little is made, however, of his other writings, which raise significant questions as to whether his approach to psychology was ever reductionist (e.g., James, 1902/2012; Stanley, 2012; Taylor, 2012). This matter is revisited later in this manuscript.

The romantic epistemological approach

Romantic scholars, contrary to those who espouse the Classical tradition, seek “neither to split living reality into its elementary components nor to represent the wealth of life’s concrete events in abstract models that lose the properties of the phenomena themselves. It is of the utmost importance to Romantics to preserve the wealth of living reality, and they aspire to a science that retains its riches” (Luria, Cole & Cole, 1979, p. 174).

Romanticism arose as a reaction to the rationalism of the Enlightenment. Romantics rejected such epistemology as reductionist, for “ignoring the forces of imagination, mystery, and sentiment” (Kaboub, 2008, p. 343). They opposed an approach aimed at dissecting information from the world to quench a thirst for knowledge; one that led to the manipulation of nature. They believed that knowledge could only be attained through the keen observation of facts and careful experimentation, and could only be attained by those who truly appreciated and respected nature. As the heyday of positivism has been called the Age of Reason, the Romantic era has also been called the Age of Reflection.

Among the representatives of Romantic scholars, few exemplify their ideal better than Johann Wolfgang von Goethe. Lauded for his masterpiece *Faustus*, the scope of his achievements in a wide range of matters is such that it is hard to decide on their relative importance. Perhaps most compelling as a demonstration of the divergence between the two opposing epistemologies under consideration are the experiments he conducted to probe into the complexities of human color perception. Goethe focused on color perception’s irreducible quality, which argued against its conceptualization as an epiphenomenon of sensation. Goethe’s painstaking experiments challenged Isaac Newton’s theory of light, the prevailing view of his time. Newton’s theory maintains that all the colors in the spectrum are contained in white light. Passing white (colorless) light through a prism results in its being decomposed into all its constituents. In attempting to replicate this, however, Goethe found that this is not necessarily the case. Instead, the perspective of the perceiver determined what colors could be “obtained”. As Goethe states: “But how I was, astonished as I looked at a white wall through the prism, that stays white!. That only where it came upon some darkened area, it showed some color, then at last, around the window sill all the

colors shone. It didn't take long before I knew there was something significant about color to be brought forth, and I spoke as through an instinct out loud, that the Newtonian teachings were false" (Wikipedia, Color Theory; see also Sepper, 2005).

The impact of this and multiple scientific discoveries in the morphology (a term he coined) of plants and animals, geology, meteorology and geology among others, attests to the versatility and power of his "*zarte empirie*" (delicate empiricism), which "may yet prove to be his most influential contribution to science" (Wahl, 2005, p. 58). The relevance of Goethe's approach to physics has been described, along with its contemporary applications. A case in point is the invention of instant photography by Edwin Land (Ribe & Steinle, 2002).

Epistemological approaches to neuroscience

In the neurosciences the positivist, or analytic, approach has been the norm for a good part of the last century. Little is heard about "romantic science", yet its importance to the "modern" view of the brain, and by implication its contributions to current approaches to the science of the mind, are underscored by Richardson:

"Historians of neuroscience, of biological psychology, and of neurology concur in viewing the late eighteenth century and early nineteenth centuries as a crucial period for the emergence of an unprecedented series of hypotheses and discoveries concerning the brain and nervous system. Only in the romantic era, in fact, was the brain established as the organ of thought [...] Equally important -and controversial- developments included the rise of comparative neuroanatomy, the framing of adaptationist and functionalist analyses of specific features of the mind and brain, a fundamental redefinition of the brain as an assemblage of parts or 'organs' rather than an undifferentiated whole, and anti-dualistic psychological models founded on the mind's embodiment, placing novel emphases on automatic and unconscious mental processes and on body-mind interaction" (Richardson, 2001, p. 2).

In a paper entitled *Knowing and knowledge: A plural approximation*, Manrique-Tisnés (2008) offers a comprehensive and well-articulated analysis of the shortcomings of the logical-empirical approach to scientific inquiry. Consonant with Richardson's arguments, he provides a number of well-founded reasons for the inescapable conclusion that an empiricist epistemology falls short of being the golden road to true knowledge, as its proponents have maintained. From the perspective of the study of executive function, it is of interest that he brings up the matter of ethics as part and parcel of the process of *knowing*, for this activity

does not take place in a vacuum, in an abstract world of *cold cognition*. Rather, perception is determined by mental structures that are acquired in the process of development in a socio-historical and political context. Those processes are unconscious, and comprise what cognitive psychologists have termed "tacit knowledge". As a corollary and a point brought to the fore by Thomas Kuhn and Karl Popper half a century ago, empirical findings are interpreted within a scientific paradigm: schemata that make up the socio-historical *zeitgeist* of the scientific enterprise. A *coup de grace* dealt to logical empiricism's tenet that truth may only be attained through reason, is that the scientific method itself proceeds on the principle of falsification (i.e., the rejection of the null hypothesis), based on empirical evidence. From this perspective, the truth is fleeting and uncertain, a way the mind seeks to gain a sense of stability in a world of uncertainties.

A leading proponent of a romantic epistemological approach to neuropsychological assessment was the Russian A.R. Luria. An assumption of Luria's formulation of executive function (e.g., Luria, 1966, 1973a & 1973b) is its interdependent relationship to cortical tone on the one hand, and its sociocultural constraints on the other (Luria, Cole & Cole, 1979). To that should be added the unique trajectory of any given individual. Whether it is possible to build a scientific corpus on higher level functions that can speak to such a level of specificity (i.e., incorporating both fluctuations in physiological state and sociocultural differences in individual experience) is a question that is at the very core of the epistemology of science in general, and cognitive neuroscience specifically.

Neurophenomenology and embodied cognition: A new epistemological approach

Thus far we have been discussing two main epistemological approaches to the study of higher cognitive functions, specifically that which has been deemed the pinnacle in their phylogenetic ascent -i.e., executive function. While the field has not reached consensus regarding its definition, that should not be a matter of concern. This is, after all, the nature of scientific inquiry: as our knowledge of a subject deepens and expands, definitions and categories change.

It is important to reiterate here the primary differences of the two epistemological approaches we have been discussing. One, *per force* reductionist, seeks to distill the essential in the world so as to arrive at the laws that govern it; the other, inclusive, seeks to incorporate the experience of reality into its explanations. For the first approach the question becomes what to leave out; for the second, how to go about integrating the myriad elements inherent in a phenomenology of experience.

The mind-body dualism proclaimed by Rene Descartes in the 16th century clearly stated that “there is a great difference between mind and body inasmuch as body is by nature always divisible, and the mind is entirely indivisible... the mind or soul of man is entirely different from the body” (Descartes, cited in McNerney, 2011, P.1). This assumption has dominated most of Western thought, which “can be summed up in two basic ideas: reason is disembodied because the mind is disembodied and reason is transcendent and universal” (McNerney, 2011).

Thus for Descartes, the mind and reason function abstractly and logically, unaffected by body states. In the words of Cowart (2005), “[t]he cognitivist/classicist research program can be defined as a rule-based, information-processing model of cognition that 1) characterizes problem-solving in terms of inputs and outputs, 2) assumes the existence of symbolic, encoded representations which enable the system to devise a solution by means of computation, and 3) maintains that cognition can be understood by focusing primarily on an organism’s internal cognitive processes (that is, specifically those involving computation and representation).”

This perspective has been challenged on various counts, but it remains the prevalent paradigm (Cowart, 2005; Wilson & Foglia, 2011). A central point of critics of the prevailing paradigm is that cognition is *embodied*, i.e., “deeply dependent upon features of the physical body of an agent... aspects of the agent’s body *beyond the brain* play a significant causal or physically constitutive role in cognitive processing”.

Weighing in on this discussion is a recent paradigm that has attempted to offer a fresh approach: Neurophenomenology (Varela, 1996; Varela, Thompson, and Rosch, 1991). At the center of this new approach is what proponents refer to as “the embodied mind”. Varela, Thompson, and Rosch (1991) introduced the concept of *enaction*, to deal with the limitations of the *representational* view. They emphasize that “the experienced world is portrayed and determined by mutual interactions between the physiology of the organism, its sensorimotor circuit and the environment... the structural coupling of brain-body-world constitutes the kernel of their program of embodied cognition, building on the classical phenomenological idea that cognitive agents bring forth a world by means of the activity of their *situated living bodies*” (Wilson & Foglia, 2011). “As the metaphor of “bringing forth a world” of meaningful experience implies: in this view, knowledge emerges through the primary agent’s bodily engagement with the environment, rather than being simply determined by and dependent upon either pre-existent situations or personal construals” (Wilson and Foglia, 2011).

Epistemology and clinical assessment of executive functions

Epistemology is the field of philosophy that concerns itself with how knowledge is acquired, with distinctions made between empirical and non-empirical methods of acquiring such knowledge. In neuropsychology, reasoning is considered an executive function, but the ability to apply logical operations and to problem-solving at an abstract level can be dissociated from the ability to carry out real-life tasks, behavior that is heavily dependent on executive functions (and which therefore also determine the acquisition of new knowledge by guiding our interaction with the environment). Adaptive behavior relies on decisions that must take into account the relative probability of events and consequences of action in an uncertain and unpredictable world. Thus, the neuropsychological assessment of a person’s ability to function successfully should incorporate the latter as well as the former abilities. In what follows, some key aspects of the study of executive functions from the analytic perspective will be briefly reviewed, then Luria’s perspective, as an example in the romantic tradition, will be presented, and lastly, an ‘embodied cognition’ approach to the assessment of executive functions will be discussed.

The Study of Executive Functions from the Analytic Perspective

Despite dating over 150 years, the scientific study of executive functions did not occupy center stage until well into the second half of the 20th century. Positivism reigned in all spheres of intellectual and scientific pursuit in the U.S.A. Behaviorism, which ironically evolved from Luria’s nemesis, Ivan Petrovich Pavlov, dominated psychology. The mind, as it was not observable, could not constitute the object of study of psychology.

In the U.S.A., the scientific study of the mind emerged in the mid-50’s, ending the behaviorist dry spell that followed the prolific and influential work of, among others, Harvard psychologist William James. This movement, that came to be known as the “Cognitive Revolution”, counted among its major forces with George Miller, Noam Chomsky, Jerome Bruner, Donald Hebb and Herb Simon, among others. Karl Pribram, a primatologist, is credited with coining the term “executive function”, which he related to the activity of the frontal lobes (Pribram, 1973; 1990). His work integrated neurophysiological data with a more traditional information-processing perspective (e.g., Miller, Galanter & Pribram, 1960). As the field matured, cognitive psychology, and later the cognitive neurosciences, would emerge as broad areas of study, as knowledge about mechanisms underlying cognition, behavior and emotion expanded.

Since then, the proliferation of published work in the neurosciences in general, and the cognitive neurosciences in particular, has been staggering; the exploration of new technologies and discoveries in the field is overwhelming, to the point that integration seems, at times, elusive. Some integrative models have appeared along the way. Bilder, in a recent article, provides a review of executive models that have attempted an integration including those advanced by Jacobsen, Halstead, Teuber, Fuster, Mishkin, Sanides, Stuss and Benson. Damasio, Mesulam and Posner have provided widely cited and useful models as well.

As his review concludes, Bilder singles out the model put forth by A.R. Luria (1964; 1973a; 1973b) and elaborated upon by his disciple Goldberg (1990b), for “its elegance and simplicity, [as it] provides an overall functional framework within which the process of executive function takes place” (Bilder, 2012, p. 4). [It thus appears that a Romantic scientist’s integrative synthesis is necessary to provide cohesiveness to the scientific quest!]. In the next section we turn to a review of this perspective.

A.R. Luria’s Romantic approach to the study of EFs

To expand on the reason why he favors a Luria-Goldberg account of executive function, Bilder states:

“A major premise of ...[this model]... is that the frontal lobes are organized in a hierarchical fashion, which Luria referred to as primary, secondary, and tertiary divisions of the frontal cortex. These primary, secondary, and tertiary divisions approximate the cytoarchitectonic divisions referring to the primary motor cortex, the premotor cortex, and the prefrontal cortex, respectively. Syndrome analysis of patients with discrete lesions showed systematic increases in the complexity of behavioral disruptions paralleling the cytoarchitectonic progression... This basic scheme has enormous explanatory power, and, with some refinements and elaborations, has been used to help understand wide-ranging lesion effects including not only elementary and complex motor syndromes, but also diverse deficits in expressive language, conceptual disorganization, and thought disorder, and more general problems in the initiation and regulation of complex behavior” (Bilder, 2012, p. 6).

It bears delving further into the nature of Luria’s analytical/romantic approach to the scientific endeavor, aptly illustrated in the work of Michael Cole on the one hand, and Oliver Sacks on the other, both scientists whose work was profoundly influenced by Luria. Cole points to the social-historical core in Luria’s science of the mind. Cole’s own

life work, cross-cultural psychology is, in many respects, a brain child of Luria and Vygotsky’s pioneering research in Central Asia in the 1930s (Luria, Cole & Cole, 1979). Cole (1990) characterized Luria’s scientific method as orthogonal to that which characterizes scientific inquiry in the U.S. Borrowing from Tupper, he contrasts the *synthetic* nature of Luria’s scientific method to the *analytic*, hypothesis-testing approach emblematic of the practice of science in the U.S. Cole explains that “whereas Luria attempts to test an overriding metatheory using data derived from clinical neurology, scientists in the analytic tradition have no overall theory, preferring instead to test specific hypotheses... and their data are derived from psychometric tests. In terms of assessment techniques, Luria’s methods are qualitative and flexible; he seeks links in functional systems, his methods are clinical-theoretical and case oriented. By contrast, North American neuropsychologists rely on... actuarial, quantitative, group studies” (Tupper, cited in Cole & Levitin, 2005, p. 35).

Oliver Sacks (1990) remarks on and identifies with the “romantic science” side to Luria’s work. He quotes Luria:

“Since the beginning of this century there has been enormous technical progress which has changed the very structure of the scientific enterprise... Reductionism, the effort to reduce complex phenomena to their elementary particles, became the guiding principle of scientific efforts. In psychology it seemed that by reducing psychological events to elementary physiological rules, we could attain the ultimate explanation of human behavior... In this atmosphere, the rich and complex picture of human behavior which had existed in the nineteenth century disappeared” (cited in Sacks, 1990, p. 183).

Luria saw both approaches as complementary and their unbalanced use as equally undesirable. Thus, he warns of the dangers of being swayed by a purely phenomenological account, one that lacks the logical rigor of a step-by-step analysis. Yet, as Sacks points out, “Luria’s own clinical experience, to which he is absolutely faithful, as well as his readings of the great 19th century clinicians, provides an overwhelming demonstration of the opposite danger- the danger of reductionism, of an analysis which finally loses the very reality it seeks to analyze” (Sacks, 1990, p. 183).

Executive functions and ‘embodied cognition’

Returning to the matter of the importance of this issue to executive function, the “cold cognition” debate that has occupied neuropsychologists since the mid- 1990s brought about a discussion in the field about the role, if any, of emotions in thinking, self-regulation and problem-solving, or whether emotions and information about physiological

states should not be considered a component of executive function. In 1994 Antonio Damasio published *Descartes' error: Emotion, reason and the human brain*. Citing the work of Varela, Thompson and Rosch (1991), among others, Damasio put forth the somatic marker hypothesis, arguing that emotions need to be integrated into, and modulate/guide cognitive reasoning towards adaptive decision-making. In the event of damage to emotion-regulating areas of the brain, either the person vacillates and cannot make a decision (i.e., can't decide which of several courses of action is better) or the person is influenced by the *immediate and most salient reinforcement value of the stimulus* before them (instead of taking into account other, associated emotions -i.e., reinforcement values) (Damasio, 1994). This results in such individuals' marrying prostitutes, gambling away life savings, and engaging in immediately reinforcing but ultimately devastating behavior. Further support for this position was provided by the introduction of the Iowa Gambling Test (Bechara, Damasio, Tranel & Damasio, 2007). With this they set out to determine whether "deciding advantageously in a complex situation [...] requires overt reasoning on declarative knowledge, namely, on facts pertaining to premises, options for action, and outcomes of actions that embody the pertinent previous experience. An alternative possibility was that overt reasoning is preceded by a non-conscious biasing step that uses neural systems other than those that support declarative knowledge" (p. 293). The study and further research supported the latter view.

The "cold" and "hot" cognition debate continued for several years, with researchers such as Denckla (1996) and Welsh & Pennington (1988) on the side of "cold" cognition, and the Iowa group siding with a "hot" cognition view. Armengol (2007) provides a review of the debate, concluding that indeed, the evidence pointed to a necessary role for emotions and values in adaptive behavior. It was concluded that indeed, reasoning and the regulation of behavior were influenced by emotions and values. Armengol (2007) expanded her discussion to include the role of social values and customs in the performance on neuropsychological tasks. Subsequent research has provided unequivocal evidence not only of the necessity of those factors in executive functioning, but has enriched our understanding of those processes with discoveries relating to the medial prefrontal cortex as a site specialized in the processing of such components of executive function. This contrasts with dorsolateral regions, concerned with tasks that could be considered more likely to engage in behaviors more traditionally associated with "cold cognition" (e.g., Bechara, Damasio & Damasio, 2000).

The assessment of executive functions in clinical practice

As could be predicted, Luria's approach to the assessment of executive and other cognitive functions in the clinic was qualitative, and driven by his extensive fund of knowledge that derived from more "analytical" scientific methods. In undertaking a neuropsychological investigation (to borrow from Anne-Lise Christensen), he elicited information from his patients by methodically presenting them with tasks to solve. This he did systematically, using procedures he developed over time, and through which he built a neuropsychological (he actually called it psychoneurological) model of the "working brain". Many of his clinical procedures are described throughout several of his books (e.g., *Higher Cortical Functions in Man*, 1966; *The Working Brain*, 1973a).

A thoughtful compilation of common clinical procedures utilized by Luria was published by Anne-Lise Christensen while observing him in the clinic. It was published in English, on Luria's recommendation (Christensen, personal communication), under the title *Luria's Neuropsychological Investigation* (Christensen, 1975). An unforeseen turn of events occurred as the manuscript reached clinicians clamoring for tools to assess the cognitive and functional capacities of individuals who presented with possible or known neurological dysfunction. A scoring and interpretive manual was created by Golden, Purisch & Hammeke (1985), and sold along with Christensen's assessment kit. This came to be known as the Luria-Nebraska Neuropsychological Battery, or LNNB. It consisted of the test items described by Christensen, which were scored along 11 scales, to which 3 were added, ostensibly, to detect "brain damage": one pathognomonic, a "profile elevation scale", and an impairment scale. Scales were also available to localize damage to right or the left hemisphere.

Papers soon appeared with titles as pointed as "Have they come to praise Luria or bury him?" (Spiers, 1981), where the argument was made that cloaking the instrument with an actuarial mantle was not only outrageous, and tantamount to an affront to Luria, but bespoke an absolute lack of understanding of the principles behind this approach. Other criticisms were levied around the incompleteness of the tool as a "comprehensive instrument" for the detection of brain damage, where a person with an unmistakable aphasia would be deemed neurologically intact on the basis of his performance on the test (Delis and Kaplan, 1982).

All in all, it must be abundantly clear that understanding brain function and dysfunction is a complex undertaking and "neuropsychology by the numbers" (as the legendary Edith Kaplan disparagingly referred to it), is a hazardous undertaking. The concept of primary and secondary

deficits is relevant here. For example, one would not wish to be evaluated by a neuropsychologist who interprets depressed scores on attention, verbal learning and recall tasks as indicators of underlying physiological disruption of all three areas. Further, a pediatric neuropsychologist who concludes, after assessing a young child, that a head injury has had minimal impact and fails to consider future difficulties caused by damage to association cortices integral to successful reading or math (that have yet to come “on-line”) would be equally negligent. Much preparation in the inter-relationship of various affective and cognitive processes is necessary before a person can be deemed qualified to assess individuals for possible neuropsychological impairment.

The positivistic approach to the assessment of executive functions

Having covered the qualitative, syndrome-driven investigation of neuropsychological functioning as practiced by Luria and his followers, we now turn to other approaches to assessing executive function: those derived from a more typical “classical”, actuarial perspective. A historical review of clinical neuropsychology in North America (mostly in the U.S.A.) is well beyond the scope of this article (but see Benton, 1991; Armengol, Kaplan & Moes, 2003; Lezak, Howieson, Bigler, & Tranel, 2012).

What is most apparent at the outset is that in contrast with the significant advances attained in the neurosciences, the clinical armamentarium available to assess this most complex set of abilities lags significantly behind. A few instruments such as the Wisconsin Card Test, the Stroop Test, Trail Making Test, Tower of London and variants that have sprouted along the way have been the major tools available for the evaluation of executive function for decades (Lezak, Howieson, Bigler, & Tranel, 2012). It is of note that despite the emphasis that American psychologists have traditionally placed on the valid, objective, reliable and accurate measurement of psychological traits, few instruments live up to those expectations (especially that purport to measure executive function). A longstanding matter of significant concern in the field has been the paucity of good normative studies for those instruments, particularly where demographic factors, which have a major impact on executive functions (e.g., Fortuny, Garolera, Hermosillo, et al., 2005; Armengol, 2007; Manly, 2005; McKay, 2003) are concerned, not to mention the issue of ecological validity. While efforts have been made to address those concerns, they are few and far between. Attempting to address diverse backgrounds of the clinical population faced by neuropsychologists in this day and age becomes quite daunting. The issues are so many and so complex that a truly fair, ecologically sensitive test that

addresses the unique sociodemographic characteristics of the individual being evaluated would practically amount to constructing a comprehensive evaluation system for a population with an $n=1$.

An alternative: A norm-informed Process Approach.

An analytic, hypothesis-driven, syndrome-guided process approach was developed by Edith Kaplan in Boston in the 1970's (Kaplan, 1988; 2002). It is based on Heinz Werner's developmental perspective where, most famously, it is the process, not the score “achieved”, that provides the examiner with the appropriate level of analysis to understand a person's neuropsychological profile. On the basis of this profile, and by engaging in systematic hypothesis-testing of factors that could be potentially contributing to a disordered function, the clinician may be better able to assist in the diagnostic process. More importantly perhaps, insights and information gained from such endeavors will provide solid knowledge about the person's unique pattern of strengths, weaknesses and strategies, for use in treatment and rehabilitation. This flexible approach lends itself not only to the assessment of individuals with various neurological injuries that require adaptations in ‘standard’ administration of the test, but can also be fruitfully applied to the assessment of individuals for whom no appropriate normative scores are available (i.e., in multi-cultural and multi-lingual settings).

This approach is very much in keeping with Luria's, and not surprisingly, Elkhonon Goldberg (1990a) sees it in this manner. A number of instruments are utilized by adherents of the Process Approach; others that have been developed along the way are also used. Administration and interpretation are approached from an epigenetic perspective, such that processes that led to a final answer or product are noted or further investigated. This is accomplished by testing components of complex tasks separately to determine how they contribute to incorrect solutions.

The Boston Process Approach was taught by Dr. Kaplan at the Boston VA Medical Center, usually to pre- or post-doctoral Psychology interns. Her approach was disseminated by herself and her students through workshops and conferences. It was, however, with the publication of The WAIS-R as a Neuropsychological Instrument in 1991 (Kaplan, Fein, Morris & Delis, 1991), that procedures commonly used in the clinic by Dr. Kaplan and her trainees began to be used more widely. The manual, which was promoted as an adjunct to the more traditional, psychometric test developed by David Wechsler, provided examiners with systematic ways to analyze an examinee's performance, and procedures to parse out the various components of complex tasks. A limited amount of normative data was available for those procedures.

The Process Approach is now so embedded in the newest instruments produced by the major assessment publishing companies that it is hard to remember a time when this approach to the assessment of neuropsychological functions was virtually unknown in the U.S.A. The important contribution of these instruments was that they provide a template by which comparable adaptations can be developed to assess not just ‘verbal learning’ and ‘executive functions’, but also a “subcomponent analysis” of the subcomponents of each of those broad areas. While normative data can be very helpful, we would argue that in some cases they can obscure significant individual differences relevant to interpretation of test performance and that it is the method of hypothesis testing and process analysis that provides their most salient contribution.

The Delis-Kaplan Executive Function System (D-KEFS, Delis, Kaplan, & Kramer, 2001) is a compilation of (a) modified versions” of already available instruments for which *process* analyses were developed, and (b) tests developed by the authors using a *process* perspective and later incorporated into the *System*. Importantly, the “System” was not conceived as a “battery” (a combined score is not calculated), and the authors make it abundantly clear that it is not to be used as such.

Another approach to address the issue of individual differences and Neurophenomenology is that of Sedó (Sedó, 2007; Sedó & DeCristóforo, 2001). Sedó has ingeniously developed instruments that rely on very low levels of education and cross-culturally accessible stimuli (e.g., up to five dots on a card, pictures of fruits, basic colors, etc.). This allows for standardized assessment of executive functions while presumably minimizing sociocultural influences. These tests have successfully been employed in a number of different cultural-linguistic settings across the world (Sedó, 2001).

CONCLUSIONS

In this paper, we have described two historically important but different epistemological approaches to human executive functions. From the positivistic perspective there is the assumption of an invariant external reality, which is registered by the senses. In contrast, the Romantic perspective endeavors to obtain an in-depth understanding of a person’s experience of the world, particularly when there has been significant neurological injury. This approach relies heavily on case studies to understand how damage to specific functional areas affects the person’s entire outlook and functional ability. This approach emphasizes the interaction and inter-dependency of different functional systems. The third and most recently developed epistemological

perspective we describe, Neurophenomenology, can in some ways be seen as an extension of the Romantic approach, but with an increased awareness of how individual experience determines the meaning of their interaction with the environment and others around them. For example, a young white male who sees a white police officer may feel an increased sense of protection and personal safety; a young black male, on the other hand, may experience apprehension and an increased sense of personal threat. The responses of either person on a task that requires concentration and problem-solving skills at that moment is likely to be affected by their different experiences of the same percept (see, for example, McKay, 2003). An ‘embodied cognition’ perspective (such as Neurophenomenology) argues that their responses are affected by their entire experience, including the affective and physiological components. Thus the fear generated by experience in one person will also produce a physiological response that fundamentally influences and determines the percept and reaction, as well as the memory of that experience.

We have described two different approaches to the assessment of executive functions that have resulted from these different epistemological conceptualizations. In the first case there is a reliance on standardized testing and normative comparisons as a basis for understanding what is essentially an invariant and modular conception of a person’s abilities. In the second case, the emphasis is on the interaction of multiple functional systems and the resulting phenomenological experience of the person. Such an approach relies on detailed observations of the processes whereby the person approaches tasks, and on hypothesis testing to determine what are primary versus secondary deficits, within a historical and developmental framework. The ‘embodied cognition’ approaches to the assessment of executive functions are still evolving. The work by the Iowa lab (Damasio, Bechara and colleagues) is an example of how somatic feedback in high and low risk situations can influence decision-making and behavior. Future extensions of this work will further explore the physiological, cognitive and affective conditions under which responses to the same task change.

Hopefully, scientists will come to the realization that just as the brain is unified in its collaboration among various processes, thinking and action proceed in the same manner. The epistemological dichotomy that has characterized human inquiry historically is reminiscent of damage to the corpus callosum, where the analytic functions of the left hemisphere are disconnected from the synthetic functions of the right. A more fine-grained analysis of the impact of differences in personal experiences on executive functions and thus behavior (i.e., ‘embodied cognition’) is an important

and timely development for clinicians. By reviewing these different approaches, we hope to provide the reader with a clearer understanding that interpretation of a test score on tasks of executive functioning depends on more than an analysis of process and understanding of the interaction of neurological systems; in fact, it should be extended to an appreciation of the person's phenomenological and biosychosocial history.

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