REVISTA NEUROCIÊNCIAS

Revisão

Freudian psychic apparatus and Luria's functional units: exploring intersections

Aparato psíquico freudiano e unidades funcionais de Luria: explorando interseções

Aparato psíquico freudiano y unidades funcionales de Luria: explorando intersecciones

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Resumo

Introdução. Neste trabalho, buscamos apontar que conceitos freudianos, como o id, ego e superego, podem encontrar equivalentes na neuroanatomia e neurobiologia. Para isso, exploramos as possíveis interseções entre o modelo teórico psicanalítico de Sigmund Freud e o modelo de unidades funcionais do neurologista Alexander Luria. Embora Freud tenha se afastado da perspectiva neurológica estritamente localizacionista das funções cerebrais, suas noções sobre a mente como um fenômeno dinâmico perduram e inspiram discussões no campo das neurociências. **Método**. Estabelecemos um paralelo entre o modelo estrutural e dinâmico de Freud e o modelo das unidades funcionais de Luria, destacando a complexa relação entre o id, ego, superego e o arcabouço neurológico. **Resultados.** Ressaltamos que, embora localizações precisas para essas estruturas possam ser evasivas, uma abordagem neurocientífica sistêmica da atividade psíquica está alinhada com a visão de Freud. Além disso, exploramos a dimensão genética e neurobiológica da proposta de Freud e discutimos como esses elementos poderiam levar a uma compreensão mais profunda das estruturas neuropsíquicas. Argumentamos que a distinção entre o id e suas estruturas diferenciadas permanece nebulosa e que o id pode ter raízes em regiões cerebrais que governam a sobrevivência básica, possuindo origem na herança genética. **Conclusão.** Este trabalho não fornece respostas definitivas, mas visa contribuir com a complexa relação entre a psicanálise de Freud e a neurobiologia. Destacamos a necessidade imperativa de investigações futuras, em especial empregando uma abordagem microscópica/reducionista da diferenciação neuropsíquica.

Unitermos. Freud; Luria; psicanálise; neurobiologia

Abstract

Introduction. In this paper, we aim to point out that Freudian concepts such as the id, ego, and superego may find equivalents in neuroanatomy/neurobiology. To this end, we explore the possible intersections between Sigmund Freud's psychoanalytic theoretical model and neurologist Alexander Luria's model of functional units. Although Freud distanced himself from the strictly localizationist neurological perspective of brain functions, his notions of the mind as a dynamic phenomenon persist and continue to inspire discussions in the field of neuroscience. **Method**. We establish a parallel between Freud's structural and dynamic model and Luria's model of functional units, highlighting the complex relationship between the id, ego, superego, and the neurological framework. **Results.** We emphasize that, although precise locations for these structures may be elusive, a systemic neuroscientific approach to psychic activity aligns with Freud's vision. Additionally, we explore the genetic and neurobiological dimensions of Freud's proposal and discuss how these elements could lead to a deeper understanding of neuropsychic structures. We argue that the distinction between the id and its differentiated structures remains nebulous, and that the id may have roots in brain regions governing basic survival, with origins in genetic inheritance. **Conclusion**. This paper does not provide definitive answers but aims to contribute to the complex relationship between Freudian

psychoanalysis and neurobiology. We emphasize the imperative need for future investigations, particularly employing a microscopic/reductionist approach to neuropsychic differentiation.
Keywords. Freud; Luria; psychoanalysis; neurobiology

Resumen

Introducción. En este trabajo, buscamos señalar que los conceptos freudianos, como el ello, yo y superyó, pueden encontrar equivalentes en la neuroanatomía/neurobiología. Para ello, exploramos las posibles intersecciones entre el modelo teórico psicoanalítico de Sigmund Freud y el modelo de unidades funcionales del neurólogo Alexander Luria. Aunque Freud se apartó de la perspectiva neurológica estrictamente localizacionista de las funciones cerebrales, sus nociones sobre la mente como un fenómeno dinámico perduran e inspiran discusiones en el campo de las neurociencias. **Método**. Establecemos un paralelo entre el modelo estructural y dinámico de Freud y el modelo de las unidades funcionales de Luria, destacando la compleja relación entre el ello, yo, superyó y el marco neurológico. **Resultados.** Subrayamos que, aunque las localizaciones precisas de estas estructuras puedan ser esquivas, un enfoque neurocientífico sistémico de la actividad psíquica está alineado con la visión de Freud. Además, exploramos la dimensión genética y neurobiológica de la propuesta de Freud y discutimos cómo estos elementos podrían llevar a una comprensión más profunda de las estructuras neuropsíquicas. Argumentamos que la distinción entre el ello y sus estructuras diferenciadas sigue siendo nebulosa y que el ello podría tener raíces en regiones cerebrales que gobiernan la supervivencia básica, con un origen en la herencia genética. **Conclusión**. Este trabajo no proporciona respuestas definitivas, pero pretende contribuir a la compleja relación entre el psicoanálisis de Freud y la neurobiología. Destacamos la necesidad imperativa de futuras investigaciones, especialmente empleando un enfoque microscópico/reduccionista de la diferenciación neuropsíquica.
Palabras clave. Freud; Luria; psicoanálisis; neurobiología

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INTRODUCTION

While there is a gap between neurological/natural explanations and social/human ones, several theoretical constructs regarding mental, brain, social, and behavioral phenomena have been based on assumptions about possible correlations between neurological/natural and social/human phenomena. Among these constructs is Sigmund Freud's psychoanalytic theory. Freud[1] began his theoretical reflections on the psyche in the neurological field, subsequently moving to what he himself called the "metapsychological" field[2]. In this process, Freud adopted and developed a dynamic conception of psychic activity, primarily derived from assumptions he put forward in the field of aphasia studies[3]. However, this conception of psychic functioning, which, after emerging, developed and remained conceptually divorced from the neurological language that gave rise to it[2].

Even in neurological discussions, Freud[3] made numerous criticisms against the concept of brain function localization advocated by the neurology of the second half of the 19th century[4]. At first glance, Freud did not accept the findings of anatomo-clinical research, which correlated brain lesions with the loss of cognitive functions, as a satisfactory explanatory means to support a coherent understanding of psychic activity[5]. In fact, his reflections on anatomo-clinical language studies[3] bring into the discussion the perspective of a complex and systemic view of brain functioning.

Freud[3] was particularly concerned not only with the specialization of regions - with their connecting pathways in the white matter - but primarily with the continuous nature of gray matter among specialized cortical regions. This was generally considered the seat of conscious mental life expression. In this perspective, Freud[3] characterized psychic activity as the activity of the gray matter of the cerebral cortex. A concept that was discussed and expanded by Freud[1] in a neurological model of psychic activity that undeniably served as the basis for the metapsychological models of 1900 (topographical model)[6] and 1923 (structural and dynamic model)[7].

In light of the above, it can be advantageous to seek a clear and explicit discussion of the possible correlations between the mental apparatus proposed by Freud - between the late 19th and early 20th centuries - and functional neuroanatomy. Such discussions can indicate the impasses, limitations, and possibilities for future discussions. In this regard, the aim of this work was to outline a clear discussion, although not with the intention of exhausting the subject, on the possible correlations between Freud's proposed psychodynamic model[7] and its representation in brain structure. For this purpose, an approximation was proposed between the psychodynamic model developed by Freud[7] and the model of functional units (fu) developed by the soviet neurologist Luria[8]. This approximation can indicate similarities as well as impasses between the models, which can serve as a means to facilitate future discussions involving Freud's theoretical conceptions and the findings of functional neuroanatomy and neurobiology.

From Freud's criticisms of localizationism

According to phrenological method, mental faculties were believed to be localized in specific areas of the brain[9]. This method was proposed by Franz Joseph Gall (1758-1828), a German physician and anatomist who was a pioneer in suggesting that different parts of the brain were responsible for different mental faculties and that these functions could be inferred from the shape of the skull[9]. This hypothesis of brain localization, though not scientific, inspired researchers such as Gustav Fritsch (1838–1927) and Eduard Hitzig (1838–1907), both of whom were German physicians/scientists who, in 1870, conducted important experiments that were fundamental for understanding and mapping brain function. Fritsch and Hitzig (1870) performed electrical stimulation experiments on the brains of dogs, specifically on the cerebral cortex, and observed that certain cortical regions elicited specific movements in particular parts of the body[10]. This indicated that specific regions of the cerebral cortex controlled specific muscle groups. Through this work, Fritsch and Hitzig contributed to the localization of the motor cortex.

In addition to Fritsch and Hitzig, Jean-Baptiste Bouillaud (1796–1881)[11], a French neurologist, made significant contributions to the understanding of brain functions, particularly in the context of language. Bouillaud is known for being one of the first researchers to propose that the capacity for language was located in the left cerebral hemisphere. He observed that lesions in this area were often associated with the loss of the ability to speak, which was a notable contribution to the localization theory of brain function[11]. Like other scientists of the time, Bouillaud was also influenced by phrenology, Gall's theory, and helped refine the idea that areas of the brain were responsible for specific functions, moving away from the pseudoscientific ideas associated with the phrenological method and promoting a more scientific approach to the study of brain functions[11]. His work helped establish the concept that specific mental functions, such as language, should be localized in specific areas of the brain, a conception that was later developed by other neuroscientists such as Paul Broca and Carl Wernick[4,12,13].

These pioneering researchers gave rise to a scientific movement known as localizationism. Localizationism studies were based on the scientific method of anatomo-clinical correlation, which aimed to identify the neurological correlates of cognitive deficits by analyzing patients with brain lesions. With the accumulation of evidence, the correlation between clinical signs and their neuroanatomical representations was gradually constructed. In fact, by the mid-19th century, anatomo-clinical correlation had already become widespread in neurology, and its assumptions were scientifically accepted for the localization of the neural correlates of basic mental processes.

However, this concept of localization was not equally effective in explaining the dynamic aspects of complex psychic processes[3]. This point of fundamental importance was addressed in Freud's first major study, "*On the Interpretation of the Aphasias: A Critical Study*" from 1891 - an important precursor to psychoanalytic theory. When Freud[3] entered the field of aphasia studies, the localizationist theory prevailed as a predominant paradigm. Based on the work of late 19th-century scientists such as Paul Broca and Carl Wernicke, specific types of aphasia were attributed to brain lesions that were specifically localized[12,13]. Literature data indicate that in 1861, Paul Broca presented his seminal work titled "*Remarques sur le siège de la faculté du langage* *articulé, suivies d'une observation d'aphémie*" at the Société d'Anthropologie of Paris. In this study, Broca detailed his observations of two patients who had suffered lesions in the left hemisphere of the brain, resulting in severe speech difficulties[13]. Upon examining these cases, Broca identified a specific lesion in the left frontal lobe, precisely in the posterior region of the inferior frontal gyrus, corresponding to Brodmann areas 44 and 45, now known as "Broca's area." This region is essential for speech production and motor planning[13]. Lesions in this area commonly result in Broca's aphasia, a condition characterized by difficulties in producing fluent speech, although language comprehension generally remains intact.

A few years later, in 1874, Carl Wernicke published his findings on the speech interpretation area, now called "Wernicke's area." Wernicke described a critical region located in the left temporal lobe, whose integrity is vital for language comprehension[14]. Lesions in this area result in Wernicke's aphasia, a condition in which the patient can produce fluent speech, but in a disorganized and nonsensical manner, with severely impaired language comprehension. Between these two critical areas of the left hemisphere, the arcuate fasciculus was also described, serving as an important white matter pathway connecting Broca's area to Wernicke's area[14]. This fasciculus was first described by the French physician and anatomist Joseph Jules Dejerine in the late 19th century, significantly contributing to the understanding of the neural networks involved in language[15].

The arcuate fasciculus is essential for integrated language processing, facilitating the connection between speech production and comprehension, which is crucial for repeating heard words and phrases. Carl Wernicke was also a pioneer in suggesting the relationship between the arcuate fasciculus and language functions[14]. In 1874, he proposed that damage to the arcuate fasciculus could lead to a specific type of aphasia known as conduction aphasia, in which the patient exhibits difficulty repeating words and phrases, despite maintaining relatively fluent speech production and adequate comprehension[14]. This hypothesis by Wernicke marked a significant advancement in understanding the neural networks underlying language, being accepted as a fundamental pillar in cognitive neuroscience. Something that Freud problematized.

For Freud, the brain had a character of "functional systems," and complex functions like language had a diffuse systemic architecture in the gray matter of the central nervous tissue[3]. Freud demonstrated a notable interest in the cortical extensions located between specialized regions. He raised significant questions about the entire cortical expanse between specialized areas, such as the then Wernicke's area and Broca's area, exploring their possible functions and not merely considering subcortical fasciculi in the white matter[3]. According to Freud's neurofunctional perspective, it can be inferred that he assumed neural excitation (Qn) should, after reaching specific points in the cortex (sensory/receptive regions), spread throughout the cortical mantle towards a motor discharge (motor regions), inducing modifications in neuronal connections and between regions, thus selecting pathways[1]. This understanding provides important insights into the relationship between experience and regional differentiation, as well as the extent of cortical lesion consequences beyond the loss of specifically localized functions. It suggests that these regions may serve as pathways for dynamic brain processing. Thus, this perspective does not negate the localizationist postulate but indicates that, beyond the importance of localization, there should be a complex correlation and possibly an overlap of functions between regions. While it is true, he emphasized a hypothetical and complex understanding of the relationship between brain anatomy and higher cognitive functions.

In this regard, it is essential to consider that in 1895, when Freud sought to clarify the neurobiological assumptions of mental processes, the focus of the discussion was not on the localization of specific brain functions but rather on the modulation of excitation flow in nervous tissue[1], as will be discussed furthe. For this, psychic activity was presumed, first and foremost, from the idea of neuronal activity, and secondly, from the concept of differentiated (or facilitated) neuronal networks. This aligns with a "neurodynamic" hypothesis of psychic activity that clearly formed the basis of his theory of the mind.

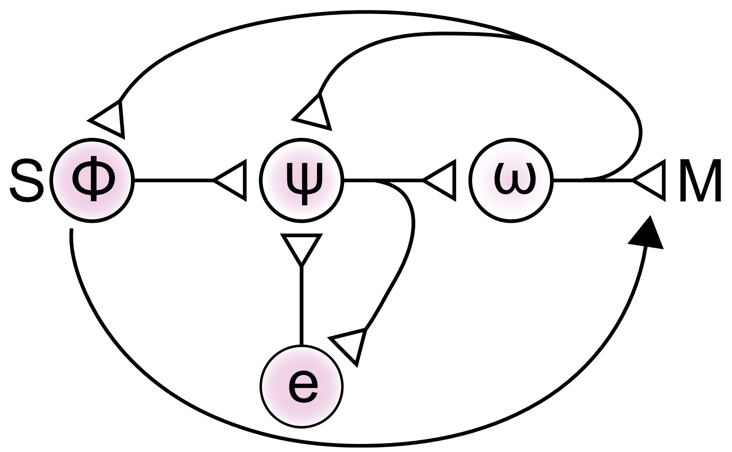
Development of the psychodynamic model

The psychodynamic conception proposed by Freud was developed between the late 19th and early 20th centuries, encompassing three fundamental theoretical models. The first was the "neurological model" of 1895, the second was the "topographical model" of 1900, and the third was the "structural and dynamic model" of 1923[1,6,7]. Freud began the elaboration of the psychodynamic model by discussing the operation of the nervous system[13].

One of the basic assumptions made by Freud was that the anatomofunctional organization of the nervous system was structured into three units: the first responsible for receiving information, the second for processing and storing traces of excitation, and the third for discharging the quantities of incoming excitation[1,16]. To illustrate this conception, Freud[1] proposed a hypothetical neurological model composed of four distinct and hierarchically organized neural types: phi cells representing sensory conduction pathways; psi cells representing the mnemonic cells of the brain; omega cells responsible for consciousness; and finally, motor conduction pathways. According to Freud[1], this neuroanatomical organization was structured - it had been selected - to rid itself of the accumulation of nervous tensions, or, in contemporary terms, to maintain homeostasis.

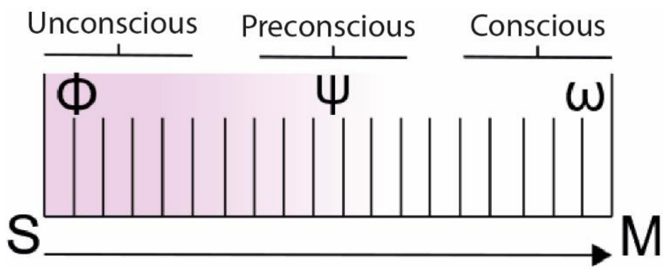
For Freud[1], the type of energy/tension at work in the nervous system was of an inherently physical nature, considering the existence of two distinct sources of tension, one exogenous and the other endogenous. In the nervous system, psychic energy was described as flowing from sensory terminations - both exogenous and endogenous - through the phi neuron system to the psi neuron system, and from there to the omega neuron system, in the direction of conscious motor discharge[1]. The scheme presented in Figure 1 was based on the descriptions proposed by Freud[1] of a basic hypothetical neuroanatomical organization for mental processes. This system would be composed of a sensory end (S) equipped with sensory receptors capable of capturing different types of environmental stimuli (e.g., light waves, sound, etc.) with specific levels and periods. The information captured in S would then be transmitted to the processing regions through the phi neuron system (Φ)[1]. Endogenous conduction pathways were also described (e), which would transmit somatic information from the interior of the organism to the central nervous system. The psi neuron system (Ψ) was described as receiving these exogenous and endogenous projections and storing memory in the form of modifications in the communication regions between neurons (synapses)[1]. Therefore, psi is characterized by its ability to receive information from both the environment and the interior of the organism, as well as by its intrinsic communication with the omega neuron system (ω). Omega was described as responsible for consciousness, with its connection to the motor system (M)[1]. Omega was also described as communicating with phi and psi[1]. These efferences to phi and psi, ultimately, would inform omega whether information received from psi originated in the environment or was produced by pure activity in psi, in other words, by thought[1].

Figure 1. Schematic model of mental functions proposed by Freud in 1895[1]. At the S end, sensory information arrives, and this information proceeds through phi (Φ) to the psi (Ψ) neuron system. In addition to the afferents from phi (Φ), psi (Ψ) receives and sends projections to the interior of the organism (e). Psi also communicates with omega (ω), omega (ω) sends motor efferents to the muscular system and sends efferents to phi (Φ) and psi (Ψ).



Already at the turn of the 19th to the 20th century, Freud[6] proposed what can be understood as a second model of the psychic apparatus, the "topographical model". This model has a virtual character and is formed by three units organized in series: the unconscious, the preconscious, and the conscious (Figure 2).

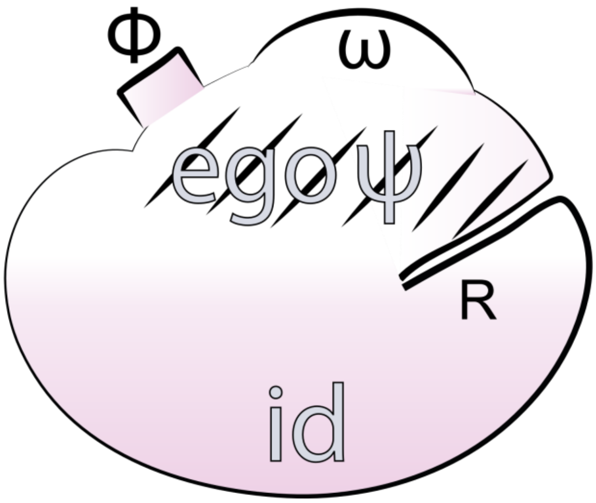
Figure 2. Schematic model of mental functions proposed by Freud in 1900[6]. The scheme was based on the model presented by Freud[6] and co-localized with the phi (Φ), psi (Ψ), and omega (ω) neuron systems described by Freud (1966[1895])[1]. Starting from a sensory end (S), a specific wave of unconscious excitation would proceed from phi (Φ) to psi (Ψ), becoming pre-conscious, reaching omega (ω) with motor discharge (M) becoming conscious. (see original model in Freud (2019[1900])[6] chap. 7).



The topographical model[6] can be described as the topographical representation of the neurological model of 1895[1], composed of a sensory end (compatible with phi), followed by an unconscious and preconscious mnemonic region (compatible with psi), and ending in a conscious motor region (compatible with omega). The flow of psychic excitation through this model was described to leave various types of mnemonic traces in the regions between the sensory end and the motor region, that is, in psi[6]. Similarly, as discussed in the neurological model[1], these records would occur due to modifications left by the flow of psychic energy, or cathexis, as Freud later came to call this energy in subsequent studies[7]. Freud[1] described that the total of these modifications generated by the interaction of the organism with the world/environment would give rise to the ego; described as a directive system responsible for selecting and regulating the organism's most effective behaviors in interaction with the environment[1].

In 1923, Freud[7] presented the final version of his construct of the psychic apparatus, the "structural and dynamic model" (Figure 3). With this model, Freud[7] sought to explain psychic activity based on the dynamic interplay between three virtual instances: the id, the ego, and the superego. The concept of the id was used to refer to the primitive/genetic basis of the psyche, derived from biological inheritance and the source of basic survival tensions, including hunger, aggression, and sexual impulses[7]. The concept of the ego, which had also been described in 1895[1], was presented in developmental/ontogenetic terms as the result of the influences of the external world on what is inherited. Finally, according to Freud[7], through the interaction of the organism with culture, the ego differentiates from the id, incorporating the values and morals of the society in which it is embedded and developed. With this construct, Freud[7] explained mental activity based on the interplay between three "psychic units," encompassing three major domains operating in a "confluent concert" for the adaptation of the organism, which are: genetic inheritance (forming the id), ontogenetic (forming the ego), and social inheritance (forming the superego).

Figure 3. Schematic model (adapted) of mental functions proposed by Freud in 1923[7]. The scheme is based on the model presented by Freud[7] and co-localized with the phi (Φ), psi (Ψ), and omega (ω) neuron systems described by Freud[1]. According to the model, what is inherited (id) is differentiated into the ego under the influence of the environment, and from the interaction of the ego with culture, the superego is differentiated as a part of the id. The id was described as the source of energy that sustains the ego and the superego. Dynamically, the id was described as interacting with the ego and objects, not only those in the external reality but also those introjected into the superego. The ego's function is to mediate the demands of the id on the external world in relation to the superego, deciding the best time to discharge its tensions. Thus, according to Freud[7], the ego is influenced by the needs of the id, the demands of the superego, and the threats of the world.



The analysis of the three previously presented models[1,6,7] suggests a progressive departure from neurobiology and neurology, which is mainly manifested through intrinsic conceptual distancing. Interestingly, an understanding of psychic activity analogous to what was proposed by Freud[7] appears in the work of the Soviet neurologist Aleksandr R. Luria[8], suggesting a sequence of the neurodynamic understanding advocated by Freud[3] — which underlies the psychodynamic conception. Luria[8] advanced the description of a neurodynamic perspective that may facilitate the meeting of Freud's postulate with a possible coherent neurofunctional basis.

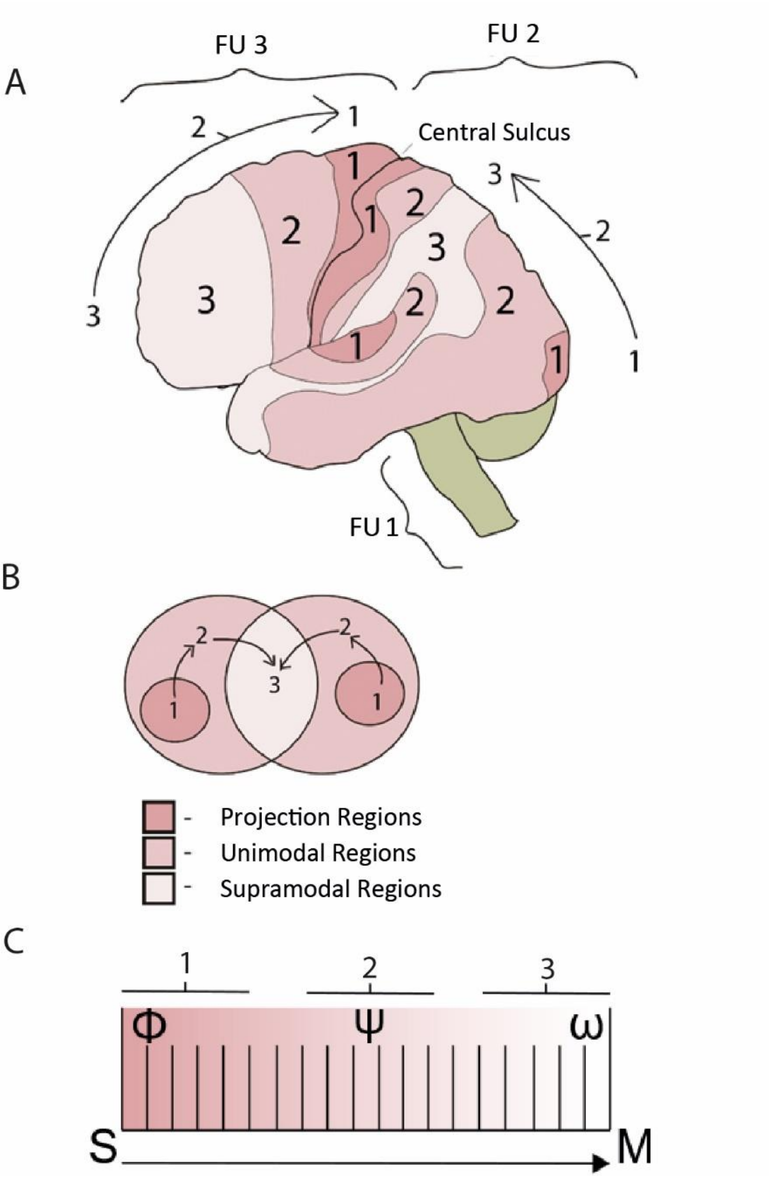
The model of functional units (fu) proposed by Luria

Luria developed the concept of "functional systems," considering that the brain is composed of regions with specific functions but operating systematically to express complex cognitive and behavioral phenomena[8]. According to this conception, the cortical regions with specific functions would receive sensory inputs (primary sensory areas) or send motor impulses (primary motor cortex) from the white matter of the brain, while the cortical extensions of gray matter between these primary regions — secondary and tertiary regions — would be involved in the complex and dynamic processing and compilation of information. It appears that Freud[3] had envisioned this type of cortical activity processing long before. To explain this process, Luria[8] divided the cerebral cortex into two major functional units, a receptive unit (fu2), encompassing the occipital, temporal, and parietal lobes, responsible for receiving, processing, and storing information. The other unit (fu3), located in the frontal lobe, consisted of the motor areas and the frontal and prefrontal regions (Figure 4). This unit is described as programming, coordinating, and verifying actions, especially conscious actions. Luria[8] also described functional unit 1 (fu1), located in the brainstem and related to the control of basic survival functions. In functional units 2 and 3, there is a hierarchical topographical organization consisting of primary areas that receive sensory inputs or send motor impulses to the periphery, secondary areas responsible for processing unimodal information (fu2) or preparing the motor program (fu3), and tertiary areas responsible for compiling the data processed by various secondary areas and producing complex forms of mental activity[8]. This model is presented in Figure 4A and 4B, and Figure 4C shows a topographical overlay with Freud's neural phi, psi, and omega neurons in the neurological model[1].

From the psychodynamic model to the model of functional units

The psychodynamic paradigm formulated by Freud[7] and the model of "functional units" postulated by Luria[8] harmonize in their appreciation of the intrinsic connection between brain and psychic processes. This harmony highlights the inherent dynamic nature of nervous and psychic activity, contributing to the construction of an evolutionary and hierarchical conceptualization of mental structure[17]. According to the "law of the hierarchical structure of cortical areas" proposed by Luria[8], there is a progressive and complex synthesis of information in cortical areas, starting from primary areas to secondary areas and from there to tertiary areas. This is complemented by the "law of decreasing specificity of hierarchically organized cortical areas," according to which primary modal areas are highly specialized, predominantly processing information from a specific sensory modality; in secondary areas, specificity is lower, and in tertiary areas, information is processed at a supramodal level.

Figure 4. Model of functional units (fu) proposed by Luria[8]. Diagram 4A represents the 3 functional units (fu) proposed by Luria: fu1 is located in the brainstem; fu2 comprises the occipital, temporal, and parietal lobes; fu3 occupies the frontal lobe. In fu2, information flows from primary regions (1) to secondary regions (2) and from there to tertiary regions (3). In fu3, it flows from tertiary regions to secondary regions and from there to primary regions (arrows). Figure 4B illustrates how a certain amount of excitation (arrows) travels from a sensory projection region 1 to unimodal sensory cortical regions (2), and from there to the supramodal region (3). After reaching the primary regions of fu2, these excitations diffuse through the anatomofunctional organization of the cerebral cortex, passing through secondary regions, where they are processed and organized, and then transmitted to tertiary regions. Tertiary regions receive information from different sensory modalities, meaning this is where information is compiled and sent to fu3. In Figure 4C, a topographical illustration shows how a wave of excitation originates from a sensory end, passing through the phi (Φ) system, corresponding to primary sensory regions, to the psi (Ψ) system, corresponding to mnemonic regions, and finally reaching the motor end via the omega (Ω) system, corresponding to tertiary regions and their extensions in fu3.



In the models of psychic activity elaborated by Freud[1,6,7], a similar hierarchical functional organization can be observed (Table 1). In the 1895 "neurological model," Freud described a hierarchical organization of function in which information would flow from the phi system (sensory) through the psi system (mnemonic) to the omega system (executive - responsible for consciousness and motor control)[1]. In the 1900 model, Freud presented the topography of the "neurological system" (proposed in the 1895 Project), inferring that as nervous information flows through the topography of the nervous system, it undergoes progressively sophisticated levels of processing - including mechanisms of resistance and repression of memories with the potential to release displeasure - toward conscious motor discharge[6]. This hierarchical topographical organization is structured as follows: at the sensory end of the system (phi), the information is unconscious, as it advances to the mnemonic region (psi), it becomes preconscious, and at the motor end (omega), it becomes conscious.

A similar hierarchical pattern is found in the structural and dynamic model of 1923, in which two sources of tension were described, one endogenous (id) and the other exogenous (sensory). These tensions move from within the organism or the environment to the preconscious regions controlled by the ego, potentially reaching conscious motor discharge[7]. These models[1,6,7] indicate that, for Freud, the convergent flow of information from various sources (regions and unimodal sensory and endogenous pathways), through the anatomofunctional organization, gives rise to complex psychic functions in supramodal regions.

Table 1. Comparison between the models of the psychic apparatus proposed by Freud (1895, 1900, 1923) and the model of functional units proposed by Luria (1962).

	Phi	**Psi**	**Ômega**
Neurological Model - 1895	System of Neurons Related to Sensory Conduction.	System of mnemonic neurons susceptible to modification by experience/activity. Site of ego differentiation.	Neuronal system responsible for consciousness/executive.
	Unconscious	**Preconscious**	**Conscious**
Topographical Model - 1900	Extension/end of receptive/sensory regions, extending into mnemonic regions housing resistances.	Mnemonic region, susceptible to modification by activity. Control of what can reach consciousness.	Executive region/endpoint. Responsible for voluntary responses.
	Id	**Ego**	**Superego**
Structural and Dynamic Model - 1923	Phylogenetic origin structure/source of basic excitation.	Id region differentiated by ontogenesis/organism-environment interaction. Control of what can reach consciousness.	Id region differentiated by the interaction of the ego with culture.
	FU I	**FU II**	**FU III**
Functional Units Model (FU) - 1962	Genetically more primitive brain regions are responsible for the control of basic survival functions, serving as the source of basic impulses and regulating cortical tone, wakefulness, and mental states, such as attention.	It encompasses cortical extensions with mnemonic and sensory/receptive regions. It acts in the processing and compilation of sensory information.	Cortical executive extension/responsible for programming/regulating and monitoring mental activity. Motor response.

In Table 1, the overlap between the models proposed by Freud (neurological 1895, topographical 1900, and structural dynamic 1923)[1,6,7] and Luria (functional systems 1947)[8] is depicted. This overlap allows us to consider, albeit with reservations, that the phi system, the unconscious, the id, and fu1 are sources of tension, more closely related to basic survival functions. The psi system, the preconscious, the ego, and fu2 are more associated with the processing of sensory inputs and memory. The omega system, the conscious, the superego, and fu3 are more related to executive control and conscious motor discharge. According to the analysis conducted thus far, the dynamic conception of psychic activity, as well as the process of its refinement[7], demonstrates notable affinities with the model of functional units[8,18,19], as detailed in Table 1. Building on this affinity, as previously explained, the concept of the id can be initially superimposed onto fu1, considering that for Freud[7], the id has a genetic basis, differentiated following heredity, and is primarily responsible for the most basic survival functions. Analogously, fu1, located in the brainstem, contains the neural nuclei responsible for the innate control of basic survival functions. It is also from fu1 that projections from the ascending reticular nucleus innervate the cerebral cortex, modulating cortical tone with impacts on processes such as alertness, attention, and vigilance[20]. In principle, these observations suggest that fu1 may be the primary neurofunctional base or nucleus from which the tensions of the id originate.

On the other hand, the concept of the ego, as defined in the "*Project for a Scientific Psychology*"[1] and in the work "*The Ego and the Id*"[7], initially allows for an overlap with cortical extensions located in fu2 and fu3. Freud[1] outlined the genesis of the ego as a result of ontogenetic modifications arising from the dynamic interaction between the organism and the environment. These modifications were conceived as integral components of a regulatory system, capable of governing the organism's behavior based on experiences acquired in past interactions[7]. These facilitations/modifications were described as occurring at synaptic junctions, facilitating integration between various cortical and subcortical areas. Freud[1] also assumed that originally the ego should have a core located in deep brain regions, which would be innervated by endogenous pathways, constantly receiving somatic excitations. Given the above, the limbic ring, due to its location and function, approximates what Freud[1] referred to as the core of the ego. The limbic cortex, situated deep within the regions of fu2 and fu3, both receives and sends projections to the interior of the organism, further communicating with cortical and subcortical areas. This arrangement allows for a cohesive response of the organism, integrating mood states, emotions, organic needs, and the perception of the external environment. It is from this core that extensions of the cerebral cortex, related to the processing of exogenous inputs, begin to form the developmental result of the ego[1]. Thus, the ego originates from the tensions of both endogenous and exogenous sources, leading to its differentiation in mnemonic neurons[1].

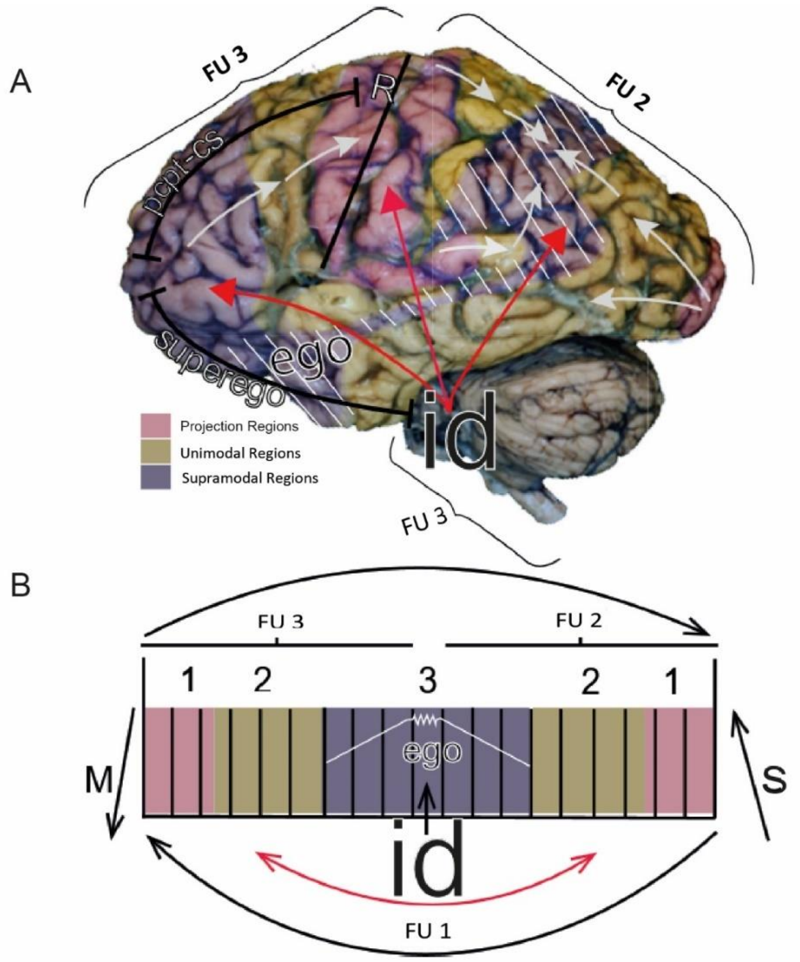
Uf2 represents an extension of the cerebral cortex involved in the reception of sensory information, processing, formation, and recall of previous states of the organism (memories)[8]. This allows us to hypothesize that the temporal, parietal, and occipital lobes may be structurally involved in the dynamics of the ego. However, it appears that not the entire extension of the fu2 cortex; Freud himself[7] argued that the ego has an auditory limit, referring to the region of projection of the auditory nerve in the left temporal lobe. Thus, it must be inferred that there are other projection regions in fu2, such as those in the parietal and occipital lobes. This raises the question of whether the remaining projection regions may be in the same condition as the auditory region. From the primary sensory regions (projection), information is processed in the secondary (unimodal) regions and compiled in the tertiary (supramodal) regions[8,18,19]. For now, this arrangement allows us to hypothesize that the entire supramodal region of fu2 may be more precisely related to the differentiated ego structure in the cortex. However, considering the characteristics of the ego and the dynamic neurofunctional view advocated by Freud[3], it would be incorrect to assume that the ego is only related to the supramodal portion posterior to the central sulcus, as this portion extends into the frontal lobe through the insula, represented by fu3. As a consequence, fu3 may also be structural for the function of the ego.

Fu3 encompasses the motor cortex, premotor regions, frontal regions, prefrontal regions, and the anterior cingulate gyrus[8]. In addition to its involvement in motor function, the frontal lobes modulate processes such as attention, memory, language, affective processes, mood, consciousness, as well as social and moral reasoning[20,21]. The frontal lobes receive information via cortical and subcortical regions, and it is in this region that impulses can lead to conscious and/or voluntary motor discharge.

Another piece of crucial evidence is related to moral and social reasoning, a function of the superego and fu3. Therefore, the frontal lobe may be one of the bases for the superego. It is not recent that evidence shows that lesions in the prefrontal region, such as in the famous case of Phineas Gage, and pathologies, as in cases of frontotemporal dementia, can affect behavior and decision-making, including moral judgment[22,23]. In addition to these pieces of evidence, studies on neurodevelopment indicate that the frontal lobe has significant development in early childhood[24]. This is a period during which specific aspects of social flexibility are processed by the frontal region, including emotional value calculation, inhibitory control of behavior, and the acquisition and generation of rule usage in different contexts. By analogy, these descriptions resemble what Freud[7] described regarding the emergence/differentiation of the superego or its function, which supports the hypothesis that frontal supramodal extensions may also be the basis for the superego. In figures 5A and 5B, a hypothetical relationship between the structural and dynamic model and the model of functional units is illustrated. The figure certainly does not precisely depict the extent of the regions and their dynamics, but rather seeks an initial approximation of the hierarchical flow of neural excitation and possible areas of differentiation. As illustrated in Figure 5A, the id has its core located in more phylogenetically primitive regions, with its origin in the brainstem represented by fu1. However, dynamically, this region can communicate bidirectionally with more recent phylogenetic regions. The psychic structures differentiated by the interaction of the organism with the environment (ego) and culture (superego) are located in extensive cortical areas, hypothetically in the supramodal regions. According to the model, the ego is mapped to the temporal lobes, extending to the frontal lobe, where it is hypothesized that differentiation with the superego occurs. This differentiation arises from the development concerning the flow of neural excitation, which originates in endogenous (id) and exogenous (sensory) regions and, through hierarchical brain organization, reaches the supramodal regions.

In Figure 5B, a hypothetical topographical model is outlined, describing this flow of cortical excitation. As can be observed, the flow begins in the primary/unconscious sensory regions (1) of functional unit 2 (fu2) and in fu1, progresses through secondary (2) regions, and culminates in the tertiary/preconscious region of fu2. Finally, in fu3, the flow of excitation proceeds from the tertiary region (3) to the secondary (2) region (premotor area), resulting in a motor response expressed in the primary (1) region (motor cortex). This model assumes that the ego should be located in an intermediate region between the sensory extremity (primary sensory regions) and the motor extremity (primary motor regions - motor cortex), mediating behavior.

Figure 5. Overlap among the structural and dynamic model proposed by Freud[7], the functional unit model proposed by Luria[8], and the flow of nervous-psychic excitation[6]. Figure 5A illustrates an intersection between Freud's structural and dynamic models and Luria's functional unit model. Figure 5B illustrates a topographical hypothesis regarding the flow of cortical excitation. In functional unit 2 (fu2), a directional progression of excitation originates at the sensory end (S) and follows a unidirectional pathway toward the primary region (1); subsequent excitation extends to the secondary region (2) and, finally, reaches the tertiary region (3). From the tertiary region (3), excitation spreads toward functional unit 3 (fu3), where it diffuses into the secondary premotor regions (2), and from there, toward the primary motor region (1), culminating in the release of the motor response (M).



Finally, it is necessary to consider that, despite Freud[3] having questioned the possibility of correlations between brain regions and complex psychic functions in his time, studies aim to correlate the Freudian model of the mental apparatus with findings in neuroanatomy and neurobiology[2]. However, Freud himself, even in his neurological writings, moved away from the perspective of the localization of functions as a means of explaining mental functions. On the other hand, it is important to reiterate that Freud[3] did not oppose the concept of specialization in brain regions. He, like Luria[8] did later, assumed a hypothetical systemic and dynamic perspective of psychic function. For Freud[3], the anatomoclinical descriptions of his time were limited, and in his inquiries into the correlation between aphasia and localized cortical lesions, for example, he assumed that connections between different circumscribed regions of the cortex and their connections in the white matter could not explain the dynamic nature of a complex function such as language. According to his perspective, the gray matter between specialized regions should participate in this process. Furthermore, due to the complex nature of psychic processes, extensive cortical extensions should act in concert. Freud[1] developed reasoning that appears to have inspired various theorists in their search for a neurological and neurobiological model for the psyche[17], a category to which Luria's work belongs. In line with this, it has been suggested that Luria's work picked up where Freud left off, specifically in the study of aphasias and the problematization of localization[17]. This contrasts with the hypothesis of processing in specific and circumscribed constellations of brain regions advocated in Freud's time by the localizationist doctrine. In addition, Solms[17] believed in the viability of the neurological assumptions defended by Freud[1] in the field of psychology; however, he also believed that some of Freud's later works seemed to be dissociated from him. In effect, this marks a significant turning point in the analysis of Freud's work in relation to neurobiology. Nevertheless, it can be inferred that the distance between Freud and the neurobiological/neurological framework partly arose from the limitations that characterized the neurobiology/neurology of his time; thus, this separation can be viewed as a transitional phase susceptible to progress[2]. In other words, Freud's proposed mental apparatus conception[7] views the mind as a dynamic phenomenon for which localization, a priori, did not find alignment with neurology. Despite this, through Luria's work, with the dynamic localization of function[8,18,20], the localization of dynamic nervous processes becomes tangible. Therefore, the type of localization proposed by Luria allows for the possibility of locating the psychological structure of a complex mental process in nervous tissue[8,18,20]. This systemic localization concept has the potential to contribute to a sophisticated discussion of Freud's major objections to the idea of localization advocated by localizationism[17]. From this perspective, a discussion of the neurological representation of Freud's psychological models becomes plausible.

Regarding the impasses of this functional relationship

As per the analysis, Freud's proposal has a genetic and neurobiological dimension that has emerged as necessary for a better understanding of his conception of the differentiation of neuropsychic structures. A more detailed analysis of Freud's[7] use of the concept of the id can shed light on this Freudian conception of the psyche, considering that the structural distinction between the id concept and its differentiated structures (ego and superego) is somewhat unclear. Likewise, there appears to be an apparent imprecision in the use of the terms as either structure or function. What is undeniably clear about the id concept is that Freud[7] refers to the primitive origin of psychic energy with it. However, thinking in terms of its structure raises a complex question regarding the extent of its localization. In Freud's understanding, the concept of the id refers, especially, to the constitutional/structural elements derived from genetic inheritance. On the other hand, under the id concept, there are other elements from different fields, including repressed memories and elements of genetic inheritance. At first glance, a biological conception of the id concept refers to the most basic impulses of life preservation and repressed memories, such as feeding, defense, and sex. Freud[7] explained that the id is a structure present even in very simple organisms, from which the ego differentiates. Therefore, this differentiation between the ego and the id is not a phenomenon found only in human organisms or in more complex organisms on the evolutionary scale.

Furthermore, understanding the id concept as a "structure" of the psychic apparatus linked to purely psychological functions seems to be too limited, as this concept has structural and genetic roots. The id concept seems to be related to the most basic elements of life, including the substrates of anatomofunctional organization and what gave rise to it. However, thinking of the id concept solely in terms of regions that regulate basic functions does not encompass all the characteristics attributed to it by Freud. Considering this perspective, not only regions of the brainstem may be related to the id, but also regions of the diencephalon and telencephalon can be included in the neuroanatomical basis of the id. In addition, the anatomical structure of the neuron itself has the constitutional elements that Freud[7] called id, as well as the elements of differentiation (ego and superego).

In this case, the cellular proteome – which defines the cell's identity and, in its differentiation, is related to external signals – fits the definition of the ego. Therefore, reductionism can be a means to generate a simpler understanding of the process of ego differentiation from what is inherited (id/genetic inheritance). This differentiation is at the core of Freud's thinking, and not just the localization itself. Here, it is suggested that differentiation can become more tangible to understanding by analyzing a simpler organism, perhaps in a single cell. Furthermore, considering that the understanding of the ontogenetic process of differentiation of regions based on inheritance as opposed to experience can be enhanced through the concept of neural networks interconnecting specific cortical and subcortical regions, this could contribute to a deeper understanding of the formation of the differentiated psychic structures presented in Figure 5.

CONCLUSION

The present work has provided a reflection that, while not covering all the complexity of the subject, allows for consideration regarding the alignment of the dynamic structural model with the model of functional units. This alignment does not necessarily imply the existence of circumscribed locations for the id, ego, or superego, but it provides a basis for discussing the systemic nature of psychic activity, as envisioned by Freud in his texts since the pre-psychoanalytic period. A more detailed analysis, on the other hand, may indicate that this systemic nature will be better understood by considering not only the regions themselves but also the process of their differentiation. In this context, the discussion of what structurally distinguishes the ego from the id is inevitable. As highlighted by Freud[7], such a difference must be attributed to extremely simple organisms since the ego emerges from the interaction of the id with the environment. From this perspective, it can be assumed that such differentiation is present even in a single cell. However, this point goes beyond the scope of a macroscopic anatomofunctional approach, which is emphasized in this work. Therefore, it is recommended that this discussion be revisited in future works with a view to a more comprehensive and in-depth understanding of the subject, especially with a microscopic approach.

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