Activation-Inhibition Coordination in Neuron, Brain, and Behavior Sequencing/Organization

Subjects: Neurosciences
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Activation-inhibition coordination is considered a dynamic process that functions as a common mechanism in the synchronization and functioning of neurons, brain, behavior, and their sequencing/organization, including over these different scales. The concept has broad applicability, for example, in applications to maladaptivity/atypicality. Young developed the hypothesis to help explain the efficacy of right-hand reaching to grasp in 1-month-olds, a study that implicated that the left hemisphere is specialized for activation-inhibition coordination. This underlying left-hemisphere function, noted to characterize the left hemisphere right from birth, can explain equally its language and fine motor skills, for example. The right hemisphere appears specialized for less complex inhibitory skills, such as outright damping/inhibition. The hypotheses related to inhibition and hemispheric specialization that appear in the literature typically refer to right hemisphere skills in these regards.

Keywords: activation-inhibition coordination ; inhibition ; laterality ; hemispheric specialization ; excitation/inhibition balance ; development ; brain networks

1. Introduction

Inhibition is a widespread mechanism in all living matter and life processes. As shall be shown, Go/NoGo Task behaviors, approach-withdrawal mechanisms, and excitation-inhibition cellular process balances are some of the tasks and concepts related to the question. As shall be shown, in high-order organisms, inhibition is central to these functions, including at the level of the neuron, regional brain networks, wider connectomics, and behavior.

2. Activation-Inhibition Coordination Modeling

2.1. A Left-Hemisphere Activation-Inhibition Coordination Model

Young developed the concept to help interpret his findings (Young et al. [1]; Young & Gagnon [2]) that 1-month-olds exhibit better-coordinated arm and hand movements in reaching for a midline object (e.g., opening the hand and then contacting the object in the proper sequence and with the proper timing), even as the left hand moves about more in a nondirected fashion as if exploring the space in which the object is contextually situated. The findings of this advantage of the right hand and arm for this activity were deemed consistent with an early hemispheric specialization along adult lines, and with the left hemisphere being specialized for fine motor skills, aside from its language-related skills, and the right hemisphere for spatial and related skills.

Young attempted to find the commonalities in the language and fine motor skills of the left hemisphere relative to those of the right hemisphere, even at this early age. He was aware of standard approaches, for example, that considered it more of an analytic hemisphere compared to the synthetic right hemisphere, but considered that the refined movements in fine motor skills and language production involved a particular coordinated dynamic of precise activation with fine-tuned inhibition of interfering movements. In this regard, the activation-inhibition coordination model could accommodate the questions posed of the common nature of the function that underlies all left-hemisphere-related skills.

That is, the concept of activation-inhibition coordination enhances understanding of the central mechanism in the brain and behavior in which inhibition participates. Rather than considering inhibition in isolation, as in research on right hemisphere inhibition, or in terms of some sort of balance, as in the balance or ratio of excitation and inhibition in neuronal synaptic activity, the concept of activation-inhibition coordination is more comprehensive, subtle, and varied.

Note that the term activation-inhibition coordination is one unique to Young. Other than references to his research, the term is not found in data engine searches in psychology and related disciplines (PsychInfo, Web of Science, Scopus, Google Scholar; 28 April 2022)

As for the specifics of the concept (see **Table 1**), Young posited that the left hemisphere is specialized for the sophisticated, longer term, and major alterations in activation-inhibition coordinations. The right hemisphere is specialized for, or can undertake less, complex inhibitions, such as outright damping or less sophisticated activation-inhibition coordinations (e.g., brief ones, or ones requiring minor adjustments).

Table 1. Different types of activation-inhibition functions in the left and right cerebral hemisphere.

Hemisphere	Type	Description
Left	**Longer term synchrony**	**Complex, sophisticated, interweaving (see next)**
	Sophisticated synchrony	**Sophisticated, subtle interweaving of activation and inhibitory skills, with appropriate activations taking place because of the suppression of interference due to inappropriate alternative behavior, both when selecting adaptive goal-directed activity and during its (movement) transitions. Both subtle competing movements and gross interfering ones are countered and controlled**
	Altering synchrony	**Majorly modifying/disrupting sequential activation-inhibition coordinations**
Right	**Adjusting synchrony**	**Minorly adapting/refining sequential activation-inhibition coordinations [could be left hemisphere based, depending on context]**
	Long damping	**Full suppression/damping activity over time**
	Short synchrony	**Activation-inhibition synchrony instantaneously or for a short time period. In spatial processes, some information as figure highlighted and some as ground moderated**

Note: The left hemisphere specializes in a sophisticated interweaving of activation and inhibitory skills. Activation-inhibition coordination especially involves the suppression of interference due to inappropriate alternative behavior, both when selecting adaptive goal-directed activity and during its (movement) transitions (e.g., in language and in fine motor activities). Adopted from Young [3] (Table 3.1, p. 56) after adaptation from Young [4][5][6][7]. Reprinted by permission from Springer International Publishing, *Causality and neo-stages in development: Toward unifying psychology*, G. Young, Copyright 2022 (Table 3.1, p. 56).

At any level of the brain-behavior system, the neuronal firing, interregional connectivity, and complex behaviors must be: properly organized, in the correct sequence, timed perfectly, controlled for intrusion from any interfering components, target/goal-oriented, and perhaps monitored throughout, depending on the level of the species involved. That is, the activation and inhibition involved must be well-coordinated to effect these tasks in an adaptive fashion.

2.2. A Generic Activation-Inhibition Coordination Model

Figure 1 presents a diagrammatic representation of the activation-inhibition coordination process that is considered ubiquitous throughout the sequencing/organization of activity in the nervous system and its supports, e.g., neurons/ the brain and its networks, and behavior. The figure represents a sequence of activities by arrows A1, A2, and A3. The model applies to the simplest organisms, even single-celled ones, and not only advanced animals from reptiles to humans. In terms of human behaviors, the activities could be thought-related or feelings/emotions, as well as internal physiology, as well as movements/actions and social activity. The activities are prompted to action by the nature of the stimuli (S) impinging on the organism, which are referred to as configured and complex. The output (R) is similarly described. The activity takes place in context and over time, which could be micro (e.g., for neuronal firing or a task) or macro (e.g., a complex undertaking, developmental time). The activity could be much more complex than represented in the figure, such as in multitasking or in social interaction. Even the simplest single-celled organisms express applicable variations in these two examples.

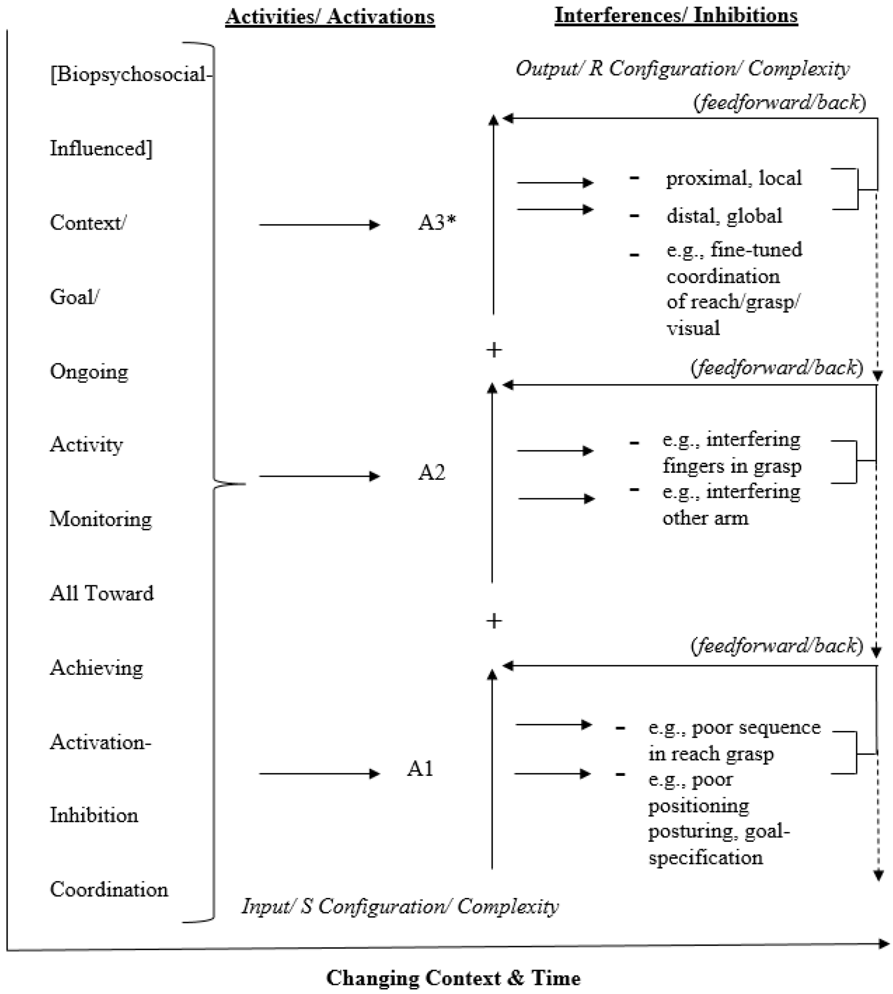

Figure 1. Mapping activation-inhibition coordination. The figure specifies an activation-inhibition coordination model that helps explain functionality at multiple scales, from neuron to brain to behavior, and their sequencing/organization. The coordination can be developmentally disturbed, go awry for multiple reasons at multiple junctures, producing aberrant activity. The modeling depicts an inhibitory plasticity, and more than inhibition as a reciprocal balance to activation/excitation in order to maintain homeostatic stability, per classic models. The model can apply to other levels in living function, for example: (a) in the genetic transcription process in which ordered activity is essential; in DNA activity; (b) when epigenetics inhibits promotor regions of DNA; (c) in single-celled animal function, in which behavior needs to be sequentially coordinated for adaptation. * Refers to sequence/organization in: (a) cellular/neuronal firing, (b) neurological/subcortical-cortical activity, and/or (c) behavior (thoughts, feelings, movements, physiology, relational/socialization).

The figure applies to different hierarchically organized levels or scales within the system involved. For example, in the connectome, Swanson et al. [8] found the equivalent of 50 sub-connectomes in analysis of the rat brain. The manner of their inter-organization would require the utmost coordination within the same regions and across them, including cortically and subcortically. This complex coordination would be exponentially greater in the human case. The posited activation-inhibition coordination process would appear one that is essential to the structuring involved in the connectome.

In order for proper, adaptive functional sequencing in context of activity, there must not only be appropriate activation, but also appropriate inhibition, as indicated. This refers to controlling potential and actual interferences. Activity is organized to inhibit both proximal/local and distal/global interferences. For example, the grasping hand needs to orchestrate proper sequences in the arm, hand, and fingers, while inhibiting surplus, interfering activities in these units and, at the same time, inhibiting contralateral mirror movements. Each individual activity in the sequence leads to feedback of its outcome, that feeds back into the system involved. The organism monitors the context, the goals involved, and the feedback, in order to ensure adaptivity instead of maladaptivity. Feedback could be forward or backward, that is either influencing upcoming activity or conditioning past activity to behave differently the next time. Adaptive activity reflects the quality of the activation-inhibition coordination involved. Multiple factors can upset this adaptivity—either inherent to the activation-inhibition coordination process or others external to it, such as general biopsychosocial factors in complex human activity (e.g., think schizophrenia, child abuse, poor motivation for whatever reason). The figure depicts an inhibitory plasticity, which involves more than suppressive inhibition because the plasticity involves a reciprocal balance in activation/excitation (inhibition) in order to maintain homeostatic stability, which is the role of inhibition in classic models.

Figure 1 graphically presents a simple sequence of activity in terms of activation (+) and inhibition (−) signs. The figure can be translated into network concepts [9] by considering the arrows as nodes and the + and − signs as links (edges). Given the complexity of behavior and its individualization, the activation-inhibition coordination networks for any one activity for any one individual will be exceedingly complex, with different nodes, links, strengths, centralities, drivers, etc.

According to Young, different types of maladaptivity can result from different lacks in the exquisite synchrony required in activation-inhibition coordination as presently defined. For example, he noted that, in Attention Deficit Hyperactivity Diosrder (ADHD), inhibition difficulties are considered critical underlying factors, and perhaps those difficulties can be reworked in terms of the concept of activation-inhibition coordination. Similarly, the disorder of schizophrenia has been described in terms of deficits in inhibitory capacities, even in terms of underlying impairments in inhibition-related interneurons and the inhibitory neurotransmitter GABA.

Whether looking at neurons or other neural/neurological activities, smooth coordination of activation and inhibition components is essential for adaptive functioning, and their disorganization in these regards can lead to maladaptivity/dysfunctionality/disorder. Young did not specify exactly how the activation-inhibition coordination might differ from one disorder/dysfunction to the next, and this remains a long term goal for work with the concept. Moreover, there are multiple scales involved, and cascades from one scale (e.g., cellular) to the next (ultimately to brain and behavior), complicate the project.

Generally, maladaptive behavior could be described in terms of: (a) excessive inhibition/suppression; (b) excessive unchecked activation; or (c) problems in the coordination of activation and inhibition. The various externalizing disorders, for example, appear to reflect an absence of the required inhibitory control, as does manic-related ones, while unipolar motivational, depressive internalizing disorders would appear to reflect an excess of the inhibition function. Coordination difficulties in these regards could manifest multiply in individual ways, for example, depending on individualized biopsychosocial impacts and vulnerabilities.

3. Clarifications

In the following, I address the major concerns of the reviewers. In essence, they asked for: (a) better conceptual clarity; (b) more on prediction/testing/falsifiability; and (c) better differentiation of the model over different scales developmentally, brain-wise (e.g., neuronally, connectomes, hemispherically), and in its application to individual differences/maladaptivity. They asked whether the model is too broad and imprecise to apply to interpreting or reworking other models, concepts, and research (e.g., approach vs. withdrawal).

3.1. Definitions

Coordination. I checked multiple online dictionaries, added my own comments, and arrived the following. The definition is expansive in order to include all dynamics and scope involved for present purposes.

Coordination is a complex characteristic of complex systems having two or more elements or units. The system could be a structure or activity. It could be internal, as in thought (at least for more complex systems, humans included), or external, as in action (which would apply to all possible systems). It could be about one system or over several or more. It could be superordinate organismic systems, or across organisms. It could be supra-organismic, as in social and political organizations. At a more complex level, it refers to a process of organizing or orchestrating the different elements/units of the system. At a simpler level, it refers to arranging or putting together the elements/units. There could be simultaneous processes involved, or sequential ones, or both. If accomplished well, the elements/units become superordinately balanced or harmonious in their relations. The coordination allows for collaborative control efficiency and effectiveness when done well. More simply, the units/elements work together smoothly, and the system internal organization, or its output, or both, are more functional/adaptive than would otherwise be the case.

In terms of how the definition of coordination applies to the concept of activation-inhibition coordination, even when considered separately, inhibition and activation are powerful processes in the structure and activity of systems. However, without their proper coordination, the system risks not being organized, efficient, and adaptive, with waste of energy/effort, and less effective action, thought, etc. Activation-inhibition coordination conditions entropy in the system, allowing for more graceful, smoother, less energetic adjustment to ongoing context, demands, needs, and efficacy requirements. In these senses, coordination is not just balance, because it implies a superordinate level to the system in which the components/units create a new level in the system involving greater sophistication pursuant to improved contextual adaptation. This is the reason why activation-inhibition coordination is a generic process that is present throughout all tiers of an applicable system, and, indeed, in any functional system, to the extent the context and the system properties allows it.

There are limits and difficulties in the process of effective activation-inhibition coordination. The system involved will have inherent limits on the number of units that it can effectively coordinate. The more complex the organism, the better the possibility of complex activation-inhibition coordination processes. The quality of the coordination could vary from one system to the next, or one organism to the next. A host of factors can affect that quality, from the collective biopsychosocial in the human case to more generic structural, relational, and ecological factors. That is, to generalize the biopsychosocial model to all organisms or entities, from the human, including in their complex social and political organizations, to the simplest, e.g., one-celled life forms, the systemic factors that can affect system output could be referred to as structural-relational-ecological.

Inhibition. Inhibition is ubiquitous in behavior, but its definition has been questioned and its bracket creep as a concept noted. Werner et al. [10] noted that, at the broadest level, inhibition has been defined as "any mechanism that reduces or dampens neuronal, mental, or behavioral activity" (Clark [11], p. 128). They gave further definitions that have emerged in the field that are too vague, imprecise, or dilute and overextend the concept. At the human behavioral level, they gave the definition of inhibition in terms of outcome rather than process, for example, in terms of strategies used to control unwanted impulses and desires.

As much as the approach to reconsidering inhibition as an outcome rather than a process (and an outcome that is actualized by the strategies people use to achieve inhibition) addresses important issues, my concern is that the proverbial baby has been thrown out with the bathwater. First, the broad definition of inhibition needs to apply to more than the human case. Second, the authors did not criticize the broad process definition they offered, taken from Clark. Third, by revising that process definition to be more inclusive of their concerns, the process approach can be improved and the definition of inhibition in this sense made more viable.

In this sense, inhibition can be defined as any mechanism that stops/dampens, contains/controls/modulates the activity of its process, and/or reduces interferences on or disruptions of ongoing neuronal, brain-related, or behavioral activity. In the human case, often this is understood as goal-directed or target-oriented, and also in the case of other organizational structures, e.g., in higher-order human institutions. This broad definition includes cognitive strategies in the human case that might be used to arrive at the inhibition, allowing for the desired/wanted/targeted outcome of inhibitory-related regulation of the activity. This definition is consistent with the present approach of activation-inhibition coordination taking place as a causal mechanism of behavior and related supports (e.g., neuronal, brain-related in the human case) at the broadest levels.

3.2. Prediction/Testing/Falsifiability

Hemispheric Specialization. Table 1 specifies how the model applies differentially to the hemispheres, and it leads to specific predictions in this regard. Furthermore, it can be extended to apply to how adaptive vs. maladaptive behavior might look. In short, many of the concerns in this section are accounted for by **Table 1**.

According to the table, as applied to hemispheric specialization, activation-inhibition coordination can take multiple forms, but the most advanced forms relate to maintaining a continuous, organized sequence in behavior at the micro-level, with ongoing moment-to-moment organization to meet adaptive goals. The left hemisphere is considered the seat of this specialized complex ongoing behavior. The left hemisphere manifests this skill in terms of its primary behavioral specializations, which include speech, manual manipulation, and related activities.

A good way of testing the model would involve kinematic analysis of verbal behavior, communicative gesture, and bimanual coordinations, either separately or together. The kinematic analysis would specify the applicable linkages in the sequence of behaviors involved from one movement to the next at the microsecond level, while indicating the way in which interfering movements are contained/controlled, or not, in an overflow/mirror fashion.

Furthermore, the model posits that complex social interactions require these skills, in that the sophisticated synchrony in activation and inhibition coordination inherent to the behavior would call for, in the proper context, the posited advanced left hemisphere activation-inhibition coordination skills. This type of hypothesis is consistent with the left hemisphere approach (vs. withdrawal) model. Approaching is more sophisticated than withdrawing, generally, given that, often, withdrawal would include social isolation, retreating using short term activation-inhibition coordination, at best, etc.

What if the social interaction is so complex in the sense that it involves ongoing dynamic behavioral and verbal interactions? Here, the context could dictate the left hemisphere engages the most sophisticated portion of the social interaction, such as the verbal one, and other components of the interaction are shunted to right hemisphere control rather than overcrowding the left hemisphere, depending on the network reserve available in the hemisphere for the interaction at hand. Or, the left hemisphere can coordinate as dominant in the activation-inhibition function with the right hemisphere, which will have a subservient, complementary, less complex role in the function. Finally, one particular behavior might invoke left hemisphere activation-inhibition coordination skills in one context, but right hemisphere ones in this regard in another. It would depend if the associated (second) behavior for the task is easier or harder than the index one. These types of conjectures are ripe for experimentation and refining the model in question.

In another example, face perception has been shown to be a right hemisphere specialization, but perhaps because other social skills in interactions require advances left hemisphere activation-inhibition coordination skills and face perception is lower-order in this regard (so is shunted to the right hemisphere in this context). Similarly, the mother might cradle the baby on the left side to engage the right hemisphere for the facial dynamic exchanges involved in the interaction, but, as well, to free the right hand (left hemisphere) for the ministrations required in caring for the baby on an ongoing basis while it is held (e.g., see Herdien et al. [12], for this possibility). The relative advantage posited for the left hemisphere for more complex social and ongoing interactions is supported by the finding that the type of emotions processed with a right hemisphere advantage are more negative than positive (e.g., see Hartikainen [13]). These types of predictions are large-scale, and kinematic analyses might show the fine-grained points in the interactions when the sophisticated activation-inhibition coordination skills posited for the left hemisphere apply well.

Maladaptivity/Atypicality. Different inhibitory deficits have been associated with different mental/behavioral disorders/conditions. As demonstrated above, developmentally, ADHD is prominent in this regard. For psychopathology, schizophrenia has been associated with inhibitory deficits over multiple scales. The manner in which these findings can be extended to difficulties in activation-inhibition coordination is difficult to specify exactly, without the basic research not having been undertaken in this regard. The basic research could take place in terms of: behavioral kinematics seeking activation-inhibition coordination dynamics and their problematic expressions; actively seeking patterns in symptom networks that reflect this function; and seeking similar patterns in brain network dynamics, including in terms of the major ones of executive function, salience, and the default model network (DMN; Ma & Zhang [14]).

Connectome. The brain is massively organized and networked into structural and functional units, often referred to as units in the connectome, intracortical networks, tract interconnectivities, etc. Neurons form internetworks from the earliest phases in development, even in the simplest organisms. The adaptive functionality of the brain or neuronal networks, as the case may be, depending on the complexity of the organism, as represented by the successful goal-directed behavior of the organism, speaks to the complex organization involved, and asks for proper explanatory mechanisms in the functioning. It is circular to say the connectome or intracortical network accomplishes or is “responsible” for the task involved, as deeper explanatory mechanisms are required. These mechanisms could be more distal, as in genetic underpinnings, or more proximal, as in the proposed activation-inhibition coordination.

Scale. How could one mechanism apply to the extreme differences in scale involved, from the lower-order individual neuronal activity, to their linkages and circuits, to upper-level intra-cortical networks, connectomes, etc., keeping in mind that even the latter will have hundreds if not thousands of sub-connectomes. The inverse question would ask how could diverse, dispersed, less economical proximal causal mechanisms be involved over different scales of a system instead of a superordinate one that cuts across the different scales of the system in the individual organism, including over cross-organism organization. Nature abhors a vacuum; as does science, and mechanism in both these cases, the concept of activation-inhibition coordination offers a compelling, even if as yet not empirically tested mechanism, for the organization involved.

What are the alternatives to cross-scale explanatory mechanisms in neuron, brain, behavior, and their organization? Do approach-withdrawal processes work? Not really, because they too require explanation beyond the simple case of one or the other component being in play. Does anything related to goal processes work, such as being on target or not, and the like? Not really, because how are target and non-target behaviors and processes themselves integrated for successful adaptive functionality?

Moreover, having one common mechanism that cuts across different scales of the system does not imply that they coordinate the components involved in the same way. Neuronal coordination is not the same in terms of brain network coordination or behavioral coordination, for example, in terms of contents. However, the underlying process remains the same despite content differences over scale. The same applies to the different contents in different organisms, different systems, e.g., the individual, the extra-personal institutional unit, and any other variation in this regard. The latter proviso includes developmentally.

Development. The cohesion afforded by one constant organizational principle that establishes neuronal, brain, and behavioral coherence, efficiency, and efficacy allows for a more adaptive growth process that can accommodate fast-changing transitions in behavior and neuron/brain. The latter conjecture is another area that would provide fertile testing ground for the hypothesis. To argue that activation-inhibition coordination cannot apply equally to different states of complexity in the growing organism misses the point that the proposed mechanism is a generic. universal one over scales yet allows for individual differences and maladaptivity/atypicality at the same time.

Networks. Borsboom [9] has developed the concept of networks as applied to symptoms, for example. It involves calculating correlation-based statistics on the linkages (edges) among the units, which are referred to as nodes. Symptom clusters do not represent latent structures; for example, the symptoms of PTSD are causally linked and act causally, and there is not a superordinate diagnostic entity that represents them. Critical nodes are considered drivers of others causally, as in poor sleep. Node clusters can be more central, coherent, cohesive, or more widely distributed and less tight, a concept that can be used to characterize left vs. right hemisphere function, for example.

Young [15] modified network theory by creating a hybrid model that included systems theory, which allows not only for symptom configurations but also for superordinate levels that can act down on symptoms. The top-down levels acting on the bottom-up ones would be akin to diagnostic categories, for example, PTSD, but individualized for the person rather than representing a uniform diagnostic category in a manual. The levels involved would mutually influence each other. Moreover, causality in the full system involved, then, would reside in more than symptom interactions and their links and causality drivers, and also even include individual appraisals, such as about the severity of the instigator trauma and the resources available to cope with it.

In terms of the applicability of the concept of networks as elaborated by Young [15] to the concept of activation-inhibition coordination—collectively, the network concepts of nodes, their linkages, specific causal drivers, superordinate levels of the system that emerge from the unit interactions and act downward to influence them, and vice versa—networks are conceived as organized in terms of activation, inhibition, and their coordinations [3]. Correlations are statistics that need explanations of their underlying connectivities and psychological relationships. Traditionally, networks are considered in terms of activations and not inhibitions, but networks needed to be considered from the multiplicity of types of activations, inhibitions, their coordinations, and disturbances/nonnormalities in this regard. The concept of networks in the Borboomian sense, and especially as modified here, is exquisitely applicable to individual differences and psychopathology, for example. As well, the combined hybrid network-system and activation-inhibition coordination concept, as proposed here, applies equally well to the different scales being discussed, including developmentally. Just as network theory has a burgeoning body of empirical research in its support, its extension into systems/different levels/different scales. Applying the activation-inhibition coordination concept to it, as proposed here, is workable, allows for predictions, is testable, and is falsifiable, as any proper modeling would require.

Implicit in the present approach is that causality exists at multiple levels, and not just the distal-proximal dimension. Just as genetics distally includes the various -omics, and epigenesis (e.g., DNA methylation due to early stressful experiences), proximally, the activation-inhibition concept needs to be complemented in understanding behavioral expression by different explanatory models, such as the biopsychosocial one (or structural-relational-ecological one), as described.

Breadth. A reviewer noted that, post hoc, the activation-inhibition model appears to explain anything and everything, so it not testable or falsifiable. To this point, I have indicated how the model can be applied, and the specific types of predictions that can be made using it, as well as the methodologies to operationalize them. Moreover, as just emphasized, the activation-inhibition coordination concept is nested in multiple causality concepts at different hierarchical levels, and so, by definition, cannot explain everything and anything.

The reviewers also noted that, problematically, potentially falsifiable evidence can be re-interpreted to support the proposed model, rendering it untestable; it is too flexible. In this regard, I note that key sets of concepts/models and data/evidence that support any theory relate to those derived from competing and prior theories in the sense to the degree they can be reworked to fit the new theory in the theory building process, while surpassing in explanatory power the other models that attempt to explain similar phenomena. Furthermore, the new model should help explain inconsistencies in other models, fill in their missing gaps, make testable predictions not possible in the other models, extend them into uncharted territories, e.g., over different domains and scales, and overall, give more coherence and elegance in the applicability of the model to its field. In this sense, reworking other models in terms of those that attempt to build on them is part of the accepted model building process and the validation of any new model. The key controls in this regard relate to explaining better extant data and data deriving from new predictions afforded by the model, and explaining better inconsistencies in the field, whether conceptual, empirical, or both. As theories build toward more inclusivity this way, the risks of trying to explain everything and anything are palpable. However, the inherent controls in the theory construction process offer criteria that either strengthen them or, at the other extreme, render them too imprecise to be contributory. The present activation-inhibition coordination concept of causal explanation of neuron, brain, behavior and their organization has been constructed to be open to being tested by the mentioned controls to model building.

In the end, activation-inhibition coordination refers to the units in the system being regulated by the processes of activation, inhibition, and their coordination, but what if the units themselves undergo changes in system development? For example, neurotransmitters change their postsynaptic consequences during development, e.g., GABAergic interneurons start out excitatory, then shift to inhibitory. For the general process involved of activation-inhibition coordination, these types of changes do not complicate understanding or application of the model; it is a generalized one that overarches specific components of the system involved, whether neuronal, brain-wide, developmental, or behavioral, as should be evident by this point. Similarly, the generic process of activation-inhibition coordination as applied to different scales will not be complicated by different activatory and inhibitory processes at the different scales, different types of activations and inhibitions anywhere in the system involved, and so on. Furthermore, in this regard, the mechanism is not inconsistent when inhibitions serve to activate behavior, activations serve to inhibit them, and so on. Neuronal inhibition could activate higher-order networks, and vice versa, and the activity of a network could contribute to activation or inhibition of behavioral expression.

3.3. Interim Conclusion

To this juncture, at the general level, the entry has presented the primary elements of the present activation-inhibition coordination model as an explanatory mechanism across scale, including developmentally and evolutionarily, in the orchestration of complex neuronal, brain-based, an behavioral sequences. Furthermore, the entry has elucidated how the model applies to differentiating the foundational specializations of the left and right brain hemispheres, with the left hemisphere considered the seat of the most complex, sophisticated organizations in this regard. At the same time, the model acknowledges that complexity along these lines varies with context/task, age/development, the species, and so on. Moreover, the contents of the activations, inhibitions, and their coordinations will vary over the different scales, e.g., developmentally, over species, over levels (neuron, brain, behavior), and the organizations involved in context/task. This does not present a problem for the model, making it too broad. Too the contrary, it emphasizes its scope, while specifying its predictability/testability/falsifiability.

The following part provides some critical supportive research on the activation-inhibition coordination concept as found in Young. Young (e.g., [3]) had examined supportive research but he found little that speaks directly to the question, given the novelty of the concept for understanding the sequencing/organization in neuron, brain, and behavior. That is, the research that Young had cited to date related to the concept addresses it indirectly, although is consistent with it. Once the relevant literature in Young [3] is reviewed below, the more recent literature is reviewed on the question. Here, research that is more directly on the concept of activation-inhibition coordination is emerging.

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