# SENSORY INTEGRATION

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# Toward a Concensus in Termonology in Sensory Integration Theory and Practice: Part 1: Taxonomy of Neurophysiological Processes


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> "When I use a word," Humpty Dumpty said in rather a scornful tone, "it means just what I choose it to mean—neither more nor less."
>
> "The question is," said Alice, "whether you can make words mean so many different things." (Carroll, 1997, p. 237)
>
> The purpose of words is communication. However, many words mean certain things only to particular people, and those words may mean something else, or even nothing to other people. We want to define the words we use because this will help [us] know what we mean. If you don't know the meaning of our words, you cannot understand our ideas. (Ayres, 1979, p. 4)

All theories include concepts, principles, and hypotheses. As we develop theories and apply them, terminology often evolves and may develop idiosyncratic meanings for various groups who use the theory. Such has been the case for the theory of sensory integration. Although individualized usage of terms can contribute to dialogue that will eventually foster further theory development, individualized usage can likewise lead to confusion in teaching or in researching related concepts. The purpose of this article is to begin the process of clarifying terminology in sensory integration theory and practice so that a consensus for teaching and building a research agenda in the field can occur.

Words and phrases will continue to have more than a single definition (e.g., in the past, persons have used *sensory integration* to refer to a neural process, a behavioral process, and a clinical frame of reference). And, clearly, those in the field of sensory integration theory and practice should question the definitions provided herein, especially in the context of teaching, clinical work, and research. Our hope is that we will refine these definitions over time and that empirical data will elucidate these complex processes. We are not attempting to establish rigid definitions. Instead, we hope to begin a dialogue that will lead to consensus in the use of terminology that reflects an understanding of the difference between theoretical and empirical definitions. This type of consensus can foster consistency in using terminology for teaching academic and continuing education courses and in building a research agenda in the field.

As occupational therapy practitioners, we have a tradition of adopting terms from the neuroscience literature and loosely adapting them in ways that we believe reflect behavior. The neuroscience literature generally presents material at the level of processes and neural mechanisms, whereas the occupational therapy literature generally conveys information at the level of experience or behavior. We believe that clarification of occupational therapy terms that overlap with standard terms from neurology and neuropsychology is a starting point for clear communication of ideas related to sensory integration theory and practice within our own field and across other disciplines.

### History of Sensory Integration Terminology

Since the time that A. Jean Ayres (1954, 1955, 1958, 1960, 1961, 1963, 1964, 1965a, 1965b, 1971) began developing sensory integration theory and treatment, the work that has emanated from her theoretical approach has used a plethora of terms to describe, identify, and explain diverse concepts related to sensory integration evaluation, treatment, and theory. Interest in sensory integration concepts appears to be experiencing a renaissance with a resurgence in research in professional journals and in the lay press (e.g., Chase, 1999; Field, 1999; Mlyniec, in press).

In this article, we present a synthesis of the suppositions and conceptualizations of numerous practitioners, researchers, and academicians to define terms related to sensory integration theory and practice. Fundamental to this article is the distinction between neurophysiological and neuropsychological views regarding sensory integration processes

## From the Chairperson

New beginnings have been on the minds of many as the new millennium begins to take shape. Such is the case for the new members of Sensory Integration Special Interest Section (SISIS) Standing Committee as we embark on projects and plans for our 3-year term. In addition to myself as the Chairperson, the committee includes Ellen Cohn, PhD, OTR/L, Clinical Associate Professor of Occupational Therapy, Boston University, Sargent College of Health and Rehabilitation Sciences, as Communication Liaison; Shelley Mulligan, PhD, OTR/L, Assistant Professor of Occupational Therapy, University of New Hampshire, as Education/Research Liaison; and Clare Summers, MA, OTR/L, Occupational Therapist, Specialist in Sensory Integration, Children's Hospital of Denver, as *Quarterly* Editor.

We will share the work of the committee through this newsletter, the Listserv, and events and meetings at American Occupational Therapy Association conferences. We welcome ideas, suggestions, concerns, and questions from the members of the SISIS and hope to participate in and accomplish a variety of important projects related to sensory integration education, practice, and research during our tenure. ■

Zoe Mailloux, MA, OTR, FAOTA

and those in our own field about the process of sensory integration function and dysfunction. In Part 1 of this series, we suggest a taxonomy of definitions related to *neurophysiological processes* in sensory integration (i.e., operations within the peripheral or central nervous system [CNS]. In Part 2 of this series, "Taxonomy for Sensory Integration Function and Dysfunction," we will differentiate these neurophysiological processes from the observable behaviors associated with functional and dysfunctional sensory integration patterns. In Part 3 of this series, "Taxonomy of Observable Behaviors Related to Patterns of Sensory Integration Dysfunction," we will provide detailed descriptive tables with examples of types of sensory integration dysfunction.

First, we will describe two basic definitions that we use throughout this article. To assist in distinguishing neurophysiological from organismic behavior, we have chosen the word *reactions* to reference neurological and physiological processes and the word *responses* to reference normal and dysfunctional observable behaviors because both neurons and people have actions, reactions, and responses.

## Neurophysiological Processes

The focus of this article is on the terms that we can best characterize as neurophysiological processes. We could use the phrase "process of" redundantly before each definition below, but we opted to delete "process of" to simplify reading and using the terms. However, we want to underscore the importance of differentiating the terminology that describes

- *processes* that we cannot and do not observe because they occur at the cellular or nervous system level and
- *behavioral manifestations* of these processes, which we can and do observe in sensory integration functions and dysfunctional patterns.

We must, as a field, begin to differentiate clearly between what we observe in children and what we infer is occurring in the CNS. Although we can infer that dysfunctional behavior patterns are related to underlying neurophysiological processes, we currently do not have the needed empirical research to prove that neurological or physiological mechanisms cause those behavior patterns.

The following neurophysiological processes relate to the action of the neurons bringing sensory input in from the environment (internal or external) to the CNS and to the action within the CNS as it handles the environmental input. The sequence begins with a physical stimulus from the environment that must be transformed into a form of energy that the CNS can use.

## The Peripheral Sensory Processes

The basics presented herein relate to general neuronal function. All neurons (sensory, motor, and interneurons) have a resting membrane potential and use two types of signaling: electrical and chemical. As information transfers from cell to cell and within cells by using these signals, it can be transformed and modified. This is what makes the CNS highly complex and able to accomplish complex functions (Kingsley, 2000). Our discussion is limited to actions within sensory neurons.

At rest, neuronal membranes have a *resting potential*, which is a small electrical imbalance between charges on the inside and outside surfaces of the membrane. The receptor primarily responsive to that signal receives an incoming sensory signal, which sets up a *receptor potential*, the first input signal. The receptor potential is a change in the balance of electrical charge on the membrane, and it relates to the strength and duration of the sensory input. Receptor potentials are local. In other words, although the change in membrane potential will travel down the membrane a short distance, its strength decreases as it moves further from the starting point. Thus, a single receptor potential will not convey the signal very far. However, receptor potentials can be summed (by using spatial and temporal summation mechanisms) to produce an *action potential*. An action potential is a brief change in ion balance on the neuron membrane that travels down the neuron and results in an electrical signal being sent along an axon to the terminal at a presynaptic site of a synapse. Action potentials are produced only when stimulus strength reaches a *threshold* for that location on the neuron. A threshold is not a set point but rather a range where an increasing probability of an action potential occurs. Multiple peripheral mechanisms can act on the receptors and influence the likelihood of attaining the threshold. Once the threshold is reached, the action potential is generated. Unlike receptor potentials, which increase in strength with increasing stimulus intensity, action potentials adhere to the all-or-none principle. Thus, to fire an action potential, stimulus intensity must reach threshold level. However, greater intensity of input does not lead to a stronger action potential.

The process just described, *transduction*, involves transforming the environmental sensory input from its initial energy state to an electrical signal. Transduction continues as this electrical signal is transformed into a chemical signal at the junction between two cells. The exact process of transduction differs between sensory systems, and for some sensory systems, the process actually occurs in the periphery at the receptor level. However, the actions that occur are consistent between and among sensory systems. The initial input is transformed into an electrical signal; the axon carries the electrical signal to synapse with cell bodies, other axons, or dendrites within the nervous system. This signal may affect nervous system activity at any and all of these synapses. The electrical signal becomes a chemical signal when it activates *neurotransmission*. Neurotransmitters are released to carry the signal between the incoming axon and its point of contact. They travel across the space between the axon and its point of contact (across the synaptic cleft) and interact with specific receptors on the postsynaptic membrane (Kandel, Schwartz, & Jessell, 1991).

Receptors are believed to be specific to one form of energy (*receptor sensitivity*) and respond best to this form of input (e.g., touch, light, temperature). However, with sufficient intensity, the receptors will fire and thereby generate neuronal signals, regardless of the form of energy used for activation. Despite the form of activation, the brain interprets the information received on the basis of the receptor and pathway from which the information arises. Thus, if you press on your eye, you will activate the visual receptors with pressure. The brain does not register pressure here; instead, you "see stars." This begins the interpretive and integrative process within the CNS. According to Kingsley (2000), "Information itself is sterile unless given meaning by association with objects and processes that are significant to the organism" (p. 145).

## The Central Sensory Processes

The following definitions relate to CNS operations involved in sensory integration processes by building on the previous discussion. These definitions are at the level of brain mechanisms, not cellular or neuronal processes.

### *Sensory Processing*

Sensory processing is an encompassing term that refers to the way in which the CNS and the peripheral nervous system manage incoming sensory information from the seven peripheral sensory systems. The reception, modulation, integration, and organization of sensory stimuli, including the behavioral responses to sensory input, are all components of sensory processing. The term *sensory processing* is similar to the term *sensory integration* when sensory integration refers to the CNS capacity to process sensory input. However, the terms are not interchangeable; sensory processing is more expansive than sensory integration because sensory integration is only one component of sensory processing.


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### *Process of Reaching a Sensory Threshold*

The process of reaching a sensory threshold exists in the periphery at the receptor level, at the level of the action potential, and at each central synapse. Peripherally, threshold refers to the minimum intensity of stimulus necessary to produce excitation or inhibition. Centrally, the process of reaching a threshold is what leads to the transmission of the electrical or chemical signal (Goldstein, 1999; Kandel et al., 1991).

### *Sensory Detection*

Sensory detection is the first step that occurs centrally. Incoming sensory information is recorded at multiple levels within the CNS so that it can affect ongoing neuronal activity (e.g., by processes such as sensitization, habituation, facilitation, suppression, inhibition, and summation) by influencing the overall level of activity in the CNS.

Occupational therapy practitioners sometimes use the term *sensory registration* when referring to persons who are underresponsive to sensation, although the physiological mechanism is more appropriately referred to as sensory *detection*, not sensory *registration*. This alteration in wording from the more specific and accurate terminology may have occurred because Ayres discussed the phenomenon of "failure to register and modulate sensory input," particularly regarding children with autism (Ayres, 1979; Ayres & Tickle, 1980).

Ayres's use of the term *registration of sensory information* (to our knowledge, Ayres did not use the terms *sensory registration* or *sensory modulation* in her work) in this context went beyond the neurological definition of sensory detection of stimuli. She used the words to allude to the way that the child's poor "awareness" of sensory stimuli is associated with a lack of attaching meaning to situations that are meaningful to most persons.

In occupational therapy, the term *poor sensory registration* has come to mean a failure to record or notice and respond to salient environmental information. Since 1980, the occupational therapy literature has used the term to refer to a person who has a generalized underresponsive and unaware pattern of responding to sensation (e.g., Dunn & Fisher, 1983), and researchers often cite Pribram and McGuinness (1975) to justify the use of the term.

Thus, the term sensory registration has been used for two decades in occupational therapy to refer to the multifaceted process by which the CNS "pays attention to" or "notices" (Ayres's word) sensory stimuli as inferred from behavior. The underlying central (CNS) processes of registration of sensation are not fully understood. The processes probably involve a complex interplay among the limbic system, reticular formation, and the cerebral cortex. Registration of sensation may be related to the orienting response, although certainly the two are not synonymous. Loosely defined, registration refers to the fact that one can orient to a stimulus without being aware of or "registering" it.

Because the term *sensory registration* is not a term that is defined in the neurophysiological literature, several persons suggested, during discussions regarding this article, that we delete the term from this list of definitions. However, if we had done so, the field would be left with the problem that some may still use the term to refer to clinically relevant behavior (e.g., "The child has poor sensory registration"). This is not an accurate use of the term because it suggests that we have identified inadequate function within a neurophysiological process. More likely, the use of this term is intended to reflect a child's presumed experience as reflected in behavior. However, a better way to phrase this would be, "The child does not register or notice sensory stimuli in his or her environment." We chose to highlight the term in this discussion in the hope that future research will clarify its meaning and usage. We will discuss the behavioral manifestations of poor ability to register or notice sensory information further in Parts 2 and 3 of this series.

### *Neuromodulation*

Neuromodulation allows the CNS to adapt output to a continuously changing internal and external environment. Both synaptic and hormonal influences modulate patterns of electrical and chemical activity in neurons. The exact mechanisms and consequences of neuromodulation are not yet fully known (Levitan & Kaczmarek, 1997).

### *Modulating Sensation*

Modulating sensation, a subtype of the broader construct *neuromodulation*, is the multifaceted central process by which the neural messages that convey information about the intensity, frequency, duration, complexity, and novelty of sensory stimuli are adjusted. Change in reactivity is not a single process but rather involves several interacting processes that alter the neurophysiological response to stimuli. Thus, depending on the combination of inputs, signals may be propagated or inhibited, and the combination of these processes will be reflected as modulation (Levitan & Kaczmarek, 1997). Sensory modulation reflects an adjustment in ongoing physiological processes to ensure internal adaptation to new or changing sensory information.

### *Intrasensory Integration*

Intrasensory integration is the central process in which sensory input from a single sensory system converges on a cluster(s) of neurons, and together they affect the activity of the neuron(s) on which they synapse (Kandel et al., 1991).

### *Intersensory Integration*

Intersensory integration is the central process in which multisensory neurons, or clusters of neurons, receive input from more than one sensory system. The input is summed, and the response of this intersensory neuron reflects the multiple input (Kandel et al., 1991).

### *Sensory Discrimination*

Sensory discrimination is the central process of distinguishing between and organizing temporal and spatial characteristics of sensory stimuli (Kingsley, 2000).

## Conclusion

Part 2 of this series in the next issue (June 2000) of the *Sensory Integration Special Interest Section Quarterly* will discuss patterns of sensory integration function and dysfunction. The patterns of function in sensory integration will include definitions and discussion of the adaptive response, the awareness of sensation, the ability to modulate sensation, the ability to discriminate sensation, and praxis. Then we will turn to definitions of patterns of dysfunction in sensory integration and will include definitions and discussion of the general term *dysfunction* in sensory integration and specific patterns of dysfunction such as dysfunction in praxis (also called *dyspraxia*), dysfunction in modulating sensation (also called *sensory modulation dysfunction*), and dysfunction in sensory discrimination. In Part 3 of this series, we will provide detailed descriptions of the types of observable behaviors that occur within various types of dysfunctional patterns.

Although we have not discussed global issues related to a family's priorities and a child's needs for functional quality-of-life goals in occupational therapy, we certainly do not mean to imply that these issues are not essential for the occupational therapy practitioner to consider in practice. Cohn and Miller (2000) have described the primary hopes for therapy outcomes of parents of children with certain sensory integration patterns of dysfunction. Generally, the themes are increased social participation, improved self-regulation, and increased perceived self-competence. These domains are what lead most of us into occupational therapy in the first place and should be embodied in our treatment priorities. We hope that by clarifying some of the definitions in the field of sensory integration, as we have in this article, the profession can have a baseline to help reduce the strife about words and turn its attention to the more meaningful global constructs that are important to the children and family members we serve. ■

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