Sensory Receptors: A Novel Mechanism for Sustained Tactile Perception

How Pulse Pressure Overcomes Receptor Adaptation to Maintain Continuous Perception

Dr. Ammar Yaseen Mansour

Abstract

This article presents a novel hypothesis to explain the persistence of tactile perception during sustained contact with static objects, despite the phenomenon of sensory receptor adaptation. Following initial contact, receptors – including Pacinian corpuscles – begin by sending a signal that reflects the actual pressure of the object, but they soon cease responding due to the dissipation of the pressure differential. The article proposes that the nervous system does not accept this sensory silence; rather, it relies on pulse pressure generated by the contraction and relaxation of local arteries to produce a cyclical pressure differential that reactivates the receptors. Consequently, continuous sensory signals are transformed into intermittent afferent impulses, which the brain interprets as the continued presence of the object, although the estimated pressure magnitude depends on the pulse pressure amplitude (ΔP) rather than the actual pressure of the object. The article also demonstrates that sensory neurons rely on graded receptor activation instead of the all-or-none law, enabling them to discriminate stimulus intensity accurately. The article concludes that pulse pressure serves as a primary driver for the sustained function of sensory receptors, and that the organism's exploitation of its internal rhythm represents an ingenious mechanism for maintaining continuous awareness of the surrounding environment.

Keywords: *Sensory receptors, Pacinian corpuscles, pulse pressure, receptor adaptation, sustained tactile perception, action pressure waves, adaptive afferent impulses, all-or-none law.*

The superficial sensory receptors (SSR_s) are present everywhere of the contact surface between the living organism and the surrounding environment. They are the communicative bridges, via which the interior interlinks with the exterior.

The sensory receptors of one sensory neuron (SN) are similar in their architecture and in their function as well. Moreover, the SSR_s of the same function should have the same architecture wherever they are present.

Each neural fiber of the dendrites supplies one SR. It forms the core of the receptor (the central neurite). The SR itself is sensible to one specific spectrum of the stimulant's energy. Whatever is the power's spectrum on which the SSR works, it is finally converted to a pressure Wave Unit. The pressure Wave Unit is one component, which is added to many other similar ones in order to build up the Action Pressure Wave [(1)]. The last is the porter of the afferent impulse.

Hereafter, I will go farther in explaining my conception about the mode of action of the SSR_s. I will take Pacinian Corpuscles as an example for two reasons. Firstly, Pacinian receptors share the other SSR_s their mode of action. Secondly, they manifest the mode of action I applaud better than the others.

The Wave Units

*In sensory neuron (SN), the **Action Pressure Wave** is built in the periphery at the root of dendrites. Then, it is directed toward the center to the terminal branches. It consists of many components, which I called the **Wave Units**. The Wave Unit is born in the Central Neurite of the SR. At the root of dendrites, the Wave Units of many similar SRs that belong to one sensory neuron emerge together to form the Action Pressure Wave (Figure 1).*

One contact stimulates the SR for one time, no matter what is the duration of that contact. In turn, the SR fires just one Wave Unit in response. Thus, one feels a flush of pain immediately when a pin penetrates his/her skin. If the pin remains planted in the skin for more time, he/she does not feel any pain. Fortunately, the pain receptors act in this way.

However, in many circumstances, it becomes vital for the living organism to continue detecting and feeling the outsider, with which it comes in contact. Otherwise, one could lose a precious object contained in his/her hand. Here again, the living organism found out a wonderful solution to meet this major need (Figure 4).

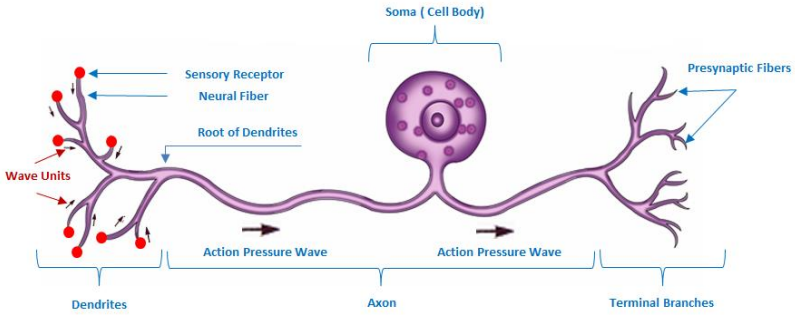


Figure (1)
The Wave Units

The Wave Unit is born in the neural fiber. At the root of the dendrites, the Wave Units of many receptors emerge together to form one Action Pressure Wave. The Action Pressure Wave propagates in the lumen of axon toward the terminal branches.

The All-or-Non-Law

Unlike the motor neurons, the sensory neurons (SN_s) do not comply with the all-or-non law [2]. In fact, the essential function of the SSR_s is to detect the least contact with the outsiders. If the SN_s comply with the all-or-non law, many of these contact-incidences will pass unperceivably (Figure 2).

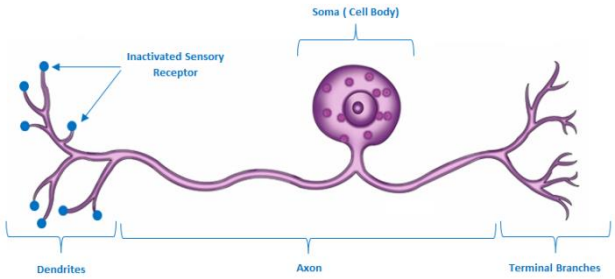


Figure (2)
Inactivated Sensory Receptors
Each sensory receptor surrounds one neural fiber of the dendrites. Herein, the sensory receptors are at rest. So I gave them the blue color.

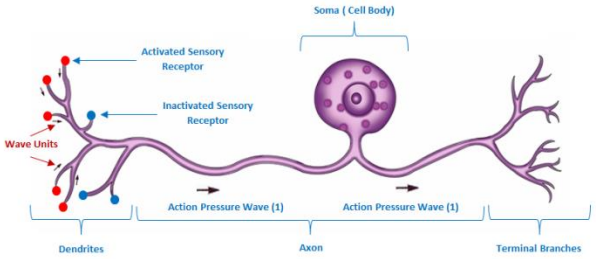


Figure (2-A)
Partially Activated Sensory Receptors

Herein, the stimulant could not stimulate but five receptors (the red balls) of the eight sensory receptors. The induced five Wave Units emerge to form on Action Pressure Wave at the root of the Dendrites. While, three sensory receptors of the same neuron remained inactive (the blue balls). The upper sensory neurons will estimate the stimulant's energy as equivalent to 5/8 of the energy of one Action Pressure Wave.

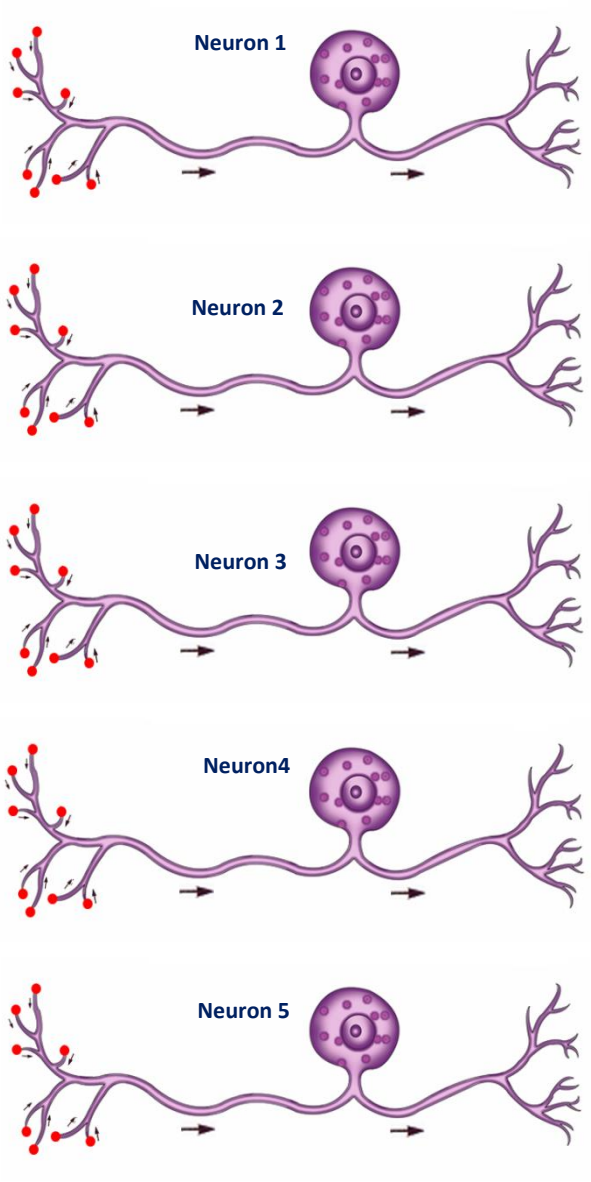


Figure (2-B)
Totally Activated Sensory Receptors of a group of five Sensory Neurons

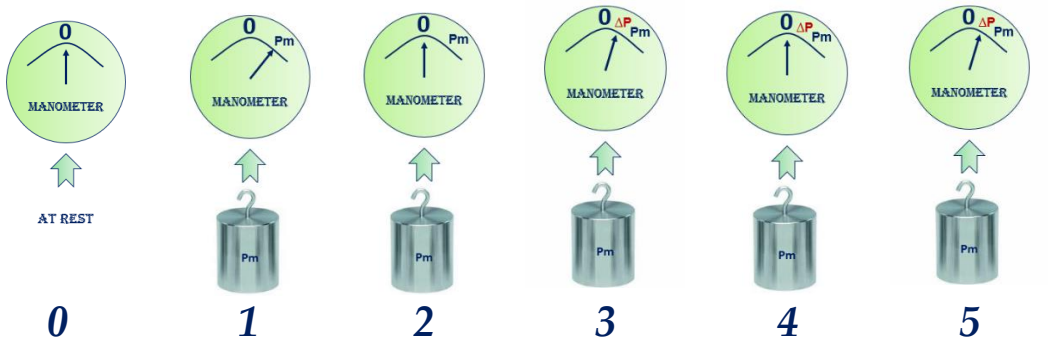
In this case, the stimulant activated all the sensory receptors of a group of five sensory neurons of the same type. All the forty sensory receptors have been stimulated by one stimulant. Every induced eight Wave Units build up one Action Pressure Wave. So, five Action Pressure Waves of full energies will arrive to the upper sensory neurons. The upper sensory centers estimate the stimulant's energy as equivalent to the sum of five Action Pressure Waves' energy.

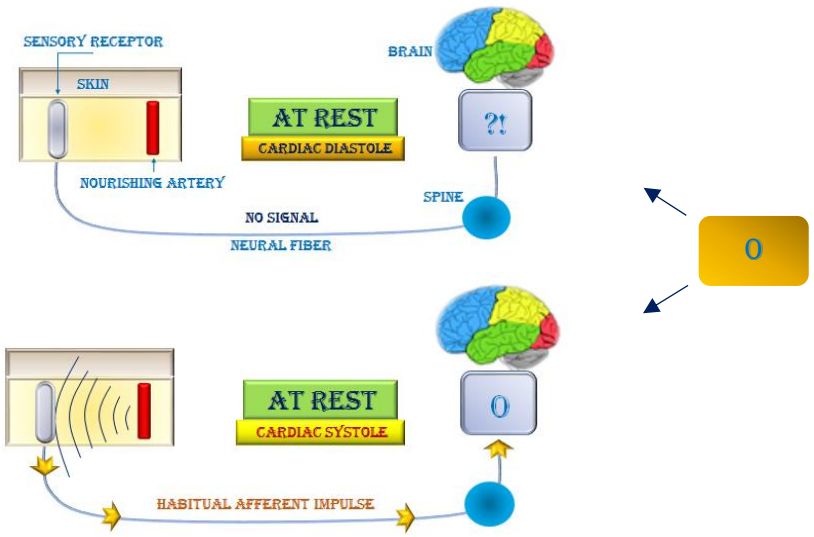
The Pressure Receptors (Pacinian Corpuscles)

Like other SSRs, Pacinian corpuscle detects the contacting stimulant immediately. It feels its precise pressure on the skin, initially. However, it tends to ignore even the existence of the object in the coming instant (Figure 4).

Indeed, it is the differential value of pressure imposed by the detected object, which activates Pacinian corpuscle. Since, this differential value of pressure will inherently fall to zero just in the coming instant, Pacinian receptor tends to lose the sensation of its contact with the stimulant. Hence after, it is due to the pulse pressure to supply the receptors with the indispensable differential value of pressure, which is a necessity for the receptors to function again and again.

Consequently, one will have just one actual reading of the contact incidence. Whereas the others that follow would be artifacts (Figure 4).





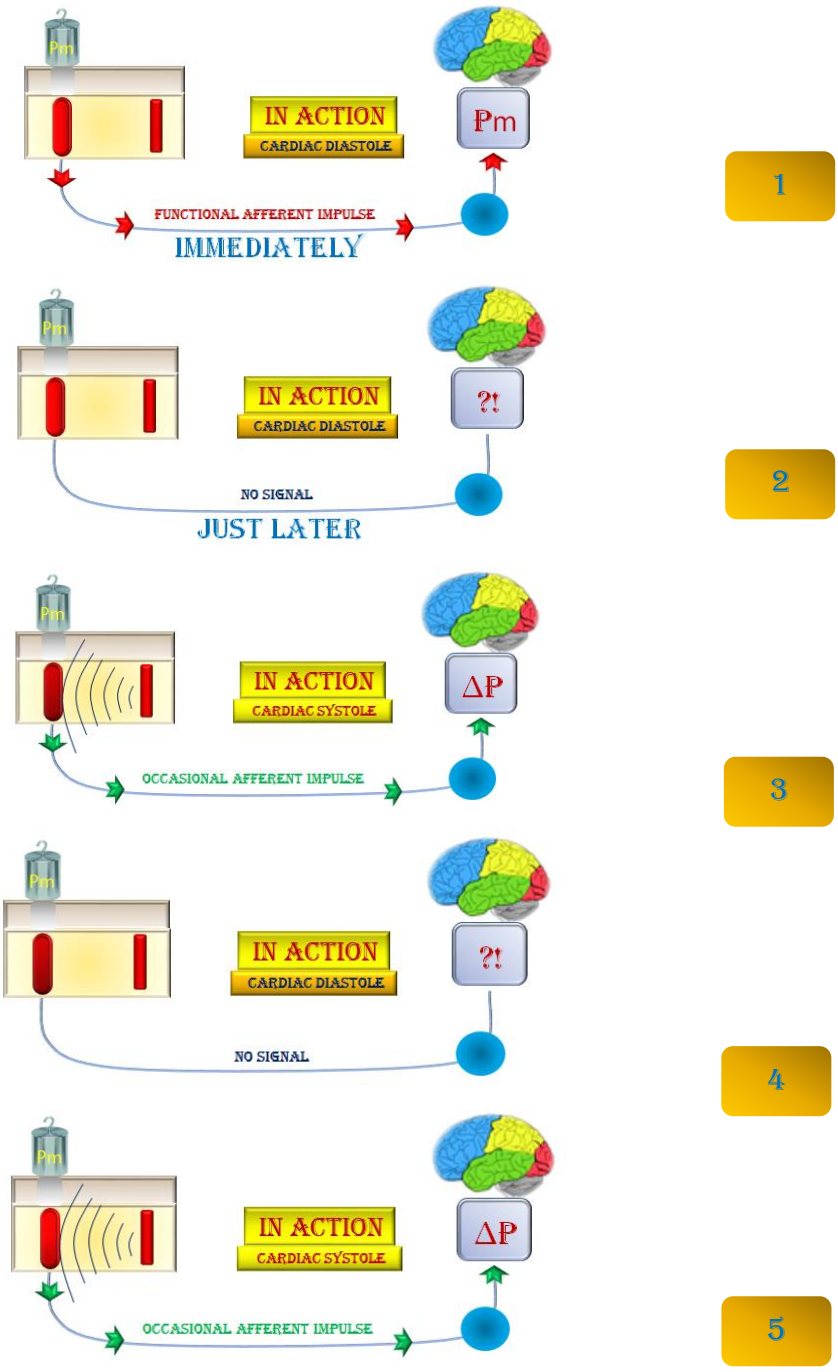


Figure (4)

: *https://youtu.be/VRTXlfXutUs*

***(0) At Rest**: There is nothing in contact. During diastolic period, the silence domains. No signals come from the periphery to the brain. The brain becomes anxious, it does not accept the void. Promptly, it recruits the pulse pressure in order to scan the tissue.*

During the systolic period, the sensory receptors respond to the scanning wave of the pulse pressure and send in turn the reassuring Habitual Afferent Impulses. Since there is nothing to scan, the brain will be satisfied with zero (0) outcome.

***(1) In Action (an object comes in contact):** Promptly, the sensory receptor*

detects the exact pressure (Pm mmHg) of the object, and responds by sending the adapted Functional Afferent Impulse to the brain. The brain interprets the Functional Afferent Impulse as it should. So, the brain estimation of the object's pressure would be close to the reality (i.e. ≈ Pm mmHg).

(2) In Action (the object is still in contact): *Just later, the sensory receptor loses the differential value and therefor stops sending afferent impulses to the brain. The brain does not accept the situation of no signals from the periphery (?!!).*

(3) In Action (the object is still in contact): *Later on, the sensory receptors receives the Pulse Pressure as a substitute differential value, and sends the Occasional afferent impulse in response. The brain will interpret the Occasional Afferent Impulse. So, the pressure estimation of the object would be about the pulse pressure itself (≈ ΔP).*

(4) In Action (the object is still in contact): *Later on, during the diastolic period, the sensory receptor does not anymore receive the pulse pressure. So, the null domains again.*

(5) In Action (the object is still in contact): *Later on, during the systolic period, the system sensory receptor-brain functions again due to the differential value of pulse pressure.*

Discussion

The pulse pressure is the only motive for all sensory receptors in order to continue detecting the least alteration in their environment. It is the origin of the inexhaustible differential value of pressure, which is indispensable for the constant function of all sensory receptors.

The pulsation of the nourishing local arteries /arterioles offers such a precious differential value of pressure. Certainly, it would be different from the differential value of pressure that is induced by the detected object itself. However, it does function perfectly and ingeniously. Thus, as much as the stimulant contacts the organism, Pacinian corpuscles keep detecting its presence, although in different way.

Actually, at rest as well as in action, the sensory receptors (such as Pacinian corpuscles) do respond to the pulse pressure regularly. Moreover, they keep sending afferent impulses to the brain in response. However, it is due to the brain per se to interpret the sensory afferent impulses as it should.

At rest, when there is nothing in contact, the afferent impulses in response to the pulse pressure would be of habitual value. So, I named them the ***Habitual Afferent Impulses****. The brain is familiar with such value, and will interpret them as nothing in contact (Figure 4-0).*

Whereas, in action also, and after the instant reading of the object that is still in contact, the afferent impulses in response to the pulse pressure becomes of different value. So, I called them the ***Occasional Afferent impulses****. Thanks to the latter, the brain keeps reading the object presence on the surface (Figure 4).*

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