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The Cerebellum Compared to the Cerebrum – The Big Brain and the Little Brain Relationship

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Unless you are involved in helping people who have had neurological problems or changes, it is highly unlikely that you would be knowledgeable about the relationship between the big brain and the little brain. You may not have even known there were two brain complexes in your head. It is also possible that you might not appreciate their relationship to the survival brain. It turns out these three players, like the skill fingers of the human hand - the thumb, index finger, and middle finger - work collaboratively to keep us alive, moving, and mastering our environment so we can thrive. The third player is called the brainstem. It is the most basic and primitive survival portion. Not considered a full brain, it does, however, manage a huge number of automatic and rhythmic pats of staying alive without thinking!

After fertilization, the *brainstem*, that primitive, rhythmic section, is the first to develop in the embryo. It is what runs the basic circuitry, provides the neurological connections to the developing fetus, and guides nourishment as the baby develops. In the newborn, it causes the heart to beat, the lungs to draw in air and blow it back out, it manages the absorption of nourishment and hydration, as well as the expulsion of waste. The big brain, the cerebral cortex, is the system, that with the help of the cranial nerves and the sensory-motor nerves, allows us to interact with the world around us. It allows us to take in data, appreciate the information, and offer a response or try something out to see, hear, or feel what happens. It allows us to be curious and use our body to get what we need to stay alive, again and again. The little brain, the cerebellum, is more involved in modulating messages and creating a fast-acting feedback loop that allows us to adjust and refine our actions and responses to get better and better at engaging, interacting, and doing what we like, want, and need.

It's interesting! The cerebellum is the little brain, yet it holds about 80% of all the neurons! They are, however, packed tightly and make up only 10% of the entire mass of the brain. The cerebral cortex only holds about 20% of all the brain's neurons, but it makes up about 80% of its mass. The cerebellum is small, but mighty. It is very compact and has densely packed, specially designed neurons that allow for rapid transmission of info in and out, both to the cerebral cortex, but also to the pons and medulla oblongata, basal ganglia, and hippocampus. The cerebral cortex, the big brain, has fewer neurons, but many more different areas of function and specialization. The synaptic connections in the cortex are much more varied and complex. The connections through the cerebellum are the ones that fine-tune and adjust the circuitry for improved reception and performance, as the pattern is repeated and more firmly established.

Just in case you are curious, do you wonder what makes up the remaining 10% of your brain mass? It may make the mass, but it actually has very few separate neurons. The remaining mass of the brain is made up of the subcortical nuclei, the transfer centers, for getting messages into the cortical and cerebellar brain regions and out to the spinal cord and body. The structures in this sub-cortical sector include the thalamus, hypothalamus, basal ganglia, mid-brain, and brain stem. The primitive survival functions and rhythm section. It is intimately wired to both the cerebellum and the cerebral cortex. When push comes to shove, it has the power to override both brains and freeze the system, put the system in reflexive flight from the threat, or push the system into a final fight for survival without thought, reason, or skill, but with intense strength. Although there are many structural supports and a great deal of white matter wiring that fill this region, there are few neurons here. These cells and structures account for only about 0.8% of all the neurons in the brain, and yet make up about 10% of the brain's mass.

Why then, do we not focus more on the cerebellum as a player in brain changes that come with dementia? Well, the fact is it tricked scientists at first because it does not dramatically shrink in the early stages of this condition. The cerebral cortex drew their attention and their eye. The shrinkage of the hippocampus and the prefrontal cortex, and the changes in the occipital and the left temporal lobes was so obvious, that those areas were noted to be the places of change. It was thought that skills that are cortically controlled, such as balance, coordination, and the ability to perform automatic and routine actions were simply not affected by Alzheimers. And since Alzheimers was thought to be the primary and pre-dominant dementia, then the cerebellum really wasn't important in the development of the brain changes of dementia until the very late stages.

So, let's take a look at what, exactly the cerebellum does for us when it is working well, and then consider the various forms of dementia and see if we can find some linkages or possible importance. Until recently, it was believed that the cerebellum only had a major role in coordinated motor type functions and postural responses such as being able to bounce a basketball while running down the court, or controlling your body while hitting a tennis ball back across a net. In other words, the ability to continue to do things that used procedural memories and automatic motions were still possible in brain changes with Alzheimers. Within the past few years, however, there is mounting evidence that the cerebellum also plays a significant role in pain reactions, attention, emotional reactions, as well as being responsible for moving the lips, tongue, and mouth structures to articulate and produce speech, and is intensely important in the ability of the eyes to work with the body to react to and respond to environmental demands and changes.

So, what role does the little brain really play in brain function? That little brain gets data from the big brain above it, and then passes it on, while also creating a feedback loop to help modulate or modify the motions, actions, and sequences to enable the person to develop more skill and perform more and more complicated and precise tasks and activities. Consider the process of learning to drive a motor vehicle. At first it is book knowledge. Pretty much all cortical. Then it is getting into the driver's seat, fastening the seat belt, going down the check list: adjust the seat (height, back angle, head rest, distance to pedals), check the mirrors (rearview, left, right), put the key in the ignition, etc. This section is a combination of sensation, movement, vision, hearing, memory, and executive function. Next comes putting the car in gear and using hands, feet, eyes, and head in a complex manner to simply control the vehicle to start and stop. Add in the amygdalae and the combination of threat, pleasure, and the desire to be independent and in charge. Next, you only drive with a driving instructor or designated controller. The external brains of the operation to monitor for the bigger picture, the safety of others, and management of the primitive brain's excitement. There is a graduated system to help ensure you master various levels of ability prior to adding in another element of risk or complexity: four-way stops, driving on an interstate, driving at night, driving with others in the car, driving in snow or rain, driving in reverse, etc. Once you have your license, you continue to develop the skills needed for greater and greater skill. This where the cerebellar action gets to be important, making minute adjustments and smoothing the rough spots so that when you use a rental car, you are comfortable and adapt without much thought, if you do it routinely. By the time you have driven for 20 years, you are on automatic pilot for most of this stuff. This demonstrated ability is mainly moderated by the combined work of your cerebral cortex, cerebellum, with alerts that come in through the cerebellar pathways and the primitive survival system when something is different, risky, or dangerous. A blow-out, black ice, or a swerving driver can trigger a survival reaction. There are many such activities we take for granted that actually involve the integration of the cerebellum into function. Many complex tasks we thought were just cerebral, apparently, use cerebellar function, and yet we are so used to it working that when it doesn't quite do its job we are startled and may perceive that there was a trick played or something outside of our control went wrong. We would not be able to realize the change came from the challenges being encountered by the changes in the little brain, not the cerebral cortex.

There is another wiring feature that is unique to the cerebellum. Instead of having wiring going from the cortical brain to the opposite side of the body, the cerebellum controls the same side of the body as the cerebellum. It may well help us integrate that fine detail, by providing alternate info to help integrate the two sides into a smooth and coordinated effort.

In other words, the cerebellum gets information from the parts of the cerebrum that help *plan a movement*. A combination of the pre-frontal cortex, the frontal cortex, and the parietal cortex. This information is sent down the spinal cord to the muscles so that the action happens. As soon as that happens, there is a feedback loop that goes from sensory organs in the muscles and joints that provide the cerebellum with positional info and movement info. The cerebellum notices whether the planned movement is accurate or needs adjustment. If all is well, not much is done. If something is not quite right, it sends messages to the cerebral areas to get modifications made. Going back to driving, it could be the re-adjustment of the side mirror to adapt to headlight glare from the car close behind you, or the checking of the tire pressure because it just feels funny and finding out it was down by about 5-8 lbs of pressure in one tire. This feedback looping also helps smooth movements and improve accuracy and efficiency of the movements to meet the desired goal or plan. For example, the ability to carry a full cup of coffee while on a bus, without spilling any on your shirt or the floor.

Different portions of the cerebellum are active in different body part actions and activities. The midline portions of the cerebellum are most involved in core trunk stability and mobility. It also serves in coordinating walking or reciprocal actions of the trunk and is critical in maintaining balance and fostering coordinated whole-body actions. The outside portions of the cerebellum are more involved in the actions of arms, legs, hands, feet, fingers, and toes. There are special sections in the cerebellum that are devoted to helping to coordinate the lips, tongue, and mouth in producing speech, as well as guiding and directing eye movements to focus on environmental features and targets.

What happens when dementia is active? It depends on the type of dementia and the degree of impact. Within the past five years, more research has been conducted regarding the changes in the cerebellum and what happens for people living with dementia. In Alzheimers, vascular dementia, and frontal lobe dementia there is mounting evidence that changes in the cerebellar area are significant and may well account for some of the changes that are noted in ability to sustain attention, control emotions, produce clear speech, and respond well to unexpected environmental stimuli. Because this is relatively new information, many providers may not be aware of these findings or pay attention to some of the alterations in ability that those living with the changes or their partners may notice.

As we move forward in our appreciation of what might help us stave off symptoms or manage life well when living with dementia, it may turn out that stimulating and supporting activities that use the functional abilities of the cerebellum are powerful forces for good. It may also be a saving grace as the disease progresses and prevents more skillful actions from happening. Continuing to dance, sing, move with a partner, rock, and sway may well provide possibilities for joy and connection, even when I spill coffee and can't drive.

