Cognitive Deficits Caused by Trigeminal Pain Stimulus

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Introduction

Securely resting in our skull is one of the most important organs – the brain. It enables us to survive, function, and maintain our representations of the world. This mass of soft tissue and blood vessels averages at about 3 pounds but provides us access to our experiences and memories that are akin to time travel (episodic) and teleportation (semantic). Its systems enable us to constantly absorb representations of the world (sensation) and understand them (perception) and customarily react to them.

A sensation is the stimulus of biological systems that occur before perception, i.e. the receptors in specific places getting activated due to a stimulus from the environment (or a command from the central nervous system). The neurons begin firing off action potentials at a rate in line with the strength of the stimuli. Perception is the process that occurs in the brain to decode the information provided by the receptors and translate it into experiences, memories, and knowledge. The perceptual process was taken for granted because many assume that sensation is perception and it "just happens". Not understanding the intricate contributions of the brain is why computer scientists have believed that perceiving machines are only a decade away for the last 70 years (Goldstein 2019). Pain is defined as an unpleasant sensory or emotional experience. Pain and pain-related diagnoses lead the globe as the most common cause of disability and disease burden with an estimated 1 in 6 adults suffering from pain and 1 in 10 chronic pain (Khera and Rangasamy 2021).

Trigeminal Pain and its Impact on Cognition

Trigeminal pain is one of the most debilitating pain stimuli we experience as classified by the International Association for the Study of Pain (IASP) and the International Headache Society (IHS). Pain can have psychological impacts and can affect our cognition through neuronal damage. This paper will survey some studies that show how some senses and cognitive processes can mitigate pain but chronic and recurring pain disrupt cognitive processes.

The Senses

Researchers have found olfactory neural networks on ancient organisms' primitive nerve cords proving that smell is the oldest of the senses. It is required to identify possible sources of food and process messages called pheromones about sexual, social, and combat information. Molecules travel up the nose and pass over the olfactory epithelium where there are millions of sensory cells. They bind to protein receptors to be detected. It doesn't take much to reach an action potential.

Taste is our sense of judging and verifying the chemicals in our surroundings that are going to be taken into our bodies. What used to be purely functional has now grown into an empire of pleasure. The five flavours (bitter, salt, sour, sweet, and umami) are sensations captured by around 10,000 taste buds. Each bud has 50 to 100 epithelial cells made up of gustatory and basal subgroups (Marieb and Hoehn 2016).

Smell and taste are cooperative senses. Taste sends its electrochemical signals to the brainstem which then relays them to the thalamus and then on to the cerebral cortex. The sensation of smell goes straight into the amygdala and olfactory cortex (both parts of the limbic system) without stopping at the thalamus (Bartoshuk and Beauchamp 1994).

The Trigeminal

The trigeminal nerve is a three-part nerve that starts in your brain and travels throughout your head. It is the system of the PNS responsible for sending pain, touch, and temperature sensations from your face to your brain. It begins as four nuclei in the brain, three sensory and one motor. The three sensory nuclei merge to form one sensory root and continue to the trigeminal ganglion. The trigeminal ganglion travels from the brainstem, specifically the Pons to the temples where it again separates into three nerve branches – the Ophthalmic, Maxillary, and Mandibular (Marieb and Hoehn 2016). The trigeminal nerves enervate most of the face.

Taste and smell as well as the trigeminal activations that are taste and smell adjacent are deeply associated with memory to the point where it can cause interference in otherwise straightforward odorant suppression tests (Cashion, Livermore,

and Hummel 2006). The association of vanilla with sweets and baking meant that it was detected even though it should have been suppressed by a much stronger odorant.

The Structure

Research that was once analytical introspection can now be confirmed via fMRI. Among the many discoveries made with fMRI, one was the location of the gustatory cortex (taste center of the brain). Electrophysiological and anatomical tract-tracing studies in non-human primates identified the dorsal anterior insula as the gustatory cortex. fMRI studies confirm this location (along with the frontal operculum) in humans (Marieb and Hoehn 2016).

The 12 cranial nerves are the parts of the peripheral nervous system that emerge from holes in the skull (foramina). They provide all of the sensory and motor information for the head and neck. The trigeminal nerve is numbered as CN V.

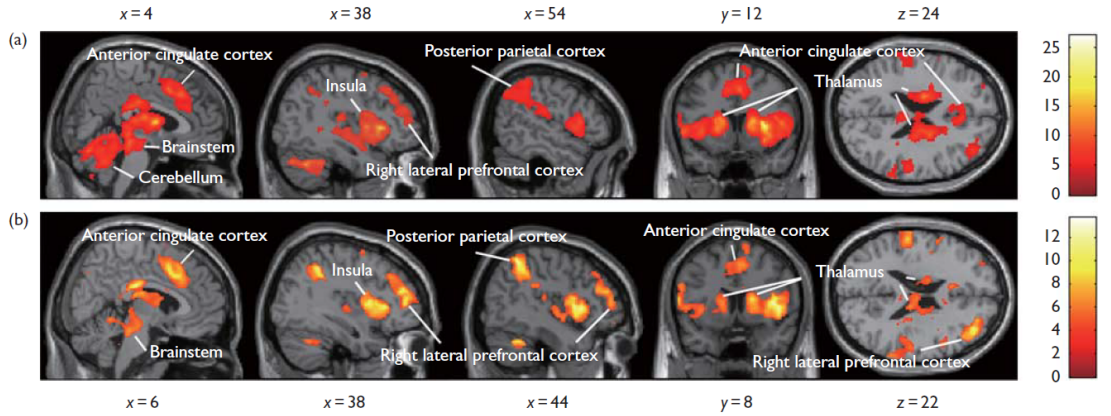
Sweet Analgesia

One example of the interplay can be seen in (Kakeda et al. 2010;Schöbel et al. 2012) where sweet taste perception protects the individual from pain such as the harsh spicy pains from capsaicin proven using fMRI imaging showing a significant analgesic effect. Sweet-derived analgesia is a result of dopamine and serotonin effects on pain. Though the analgesic effect has been conclusively demonstrated in rats and infant humans, before MRI it was debated whether it existed in adult humans at all. It is now accepted that it does exist. Figure 1 shows the effect in action across the "pain matrix".

Figure 1 shows a much larger activation of the prefrontal cortex. This may be related to the participants' anticipation (placebo effect) as the study wasn't completely blind or it may be serving some higher-order function leading to the descending analgesic system (Kakeda et al. 2010).

Figure 1

Brain Activation Sweet vs Non-Sweet



Brain activation in each contrast: (a) Nonsweet contrast and (b) sweet contrast. A height threshold of $P<0.001$ at the voxel level was employed. The corresponding t value is shown in the color scale on the right side for each contrast.

Note. Taken from Kakeda et al. 2010

A Scientific Limitation

This presents a problem in using common cooking or household odorants for testing. They have engaged several memory systems and provide so many retrieval cues unrelated to the experiment at hand that the interplay throws off the results and needs to be controlled. Using less common chemicals for testing avoids this but it is harder to find the proper types and levels. Many of the compounds used to produce the spicy effect (capsaicin – red peppers, piperine – black peppers, and gingerol – ginger) are used in foods and will make it hard to properly train and test for them.

Selective Attention

Nasal cavities so that some smells such as hot chillies or ammonia can trigger pain. These triggers can affect selective attention. In the case of low to moderate olfactory/trigeminal stimulation with nicotine, the cooling and smell components of varied menthol stimulation can be detected but this information does not come

through in the case of a higher pain stimulus provided by a greater concentration of nicotine. The pain component of the menthol stimulus is still detectable (Renner and Schreiber 2012). The explanation for this is pain processing systems' preferential seizure of selective attention (Spence et al. 2002). This implies we chose to focus on the fact that our nasal cavity is stinging, rather than the mint smell. Conversely, when a high neural load task is given to a subject (focusing their selective attention), their perception of pain decreases significantly.

Trigeminal Neuralgia

Studies show chemical irritation is not the only cause of trigeminal nerve pains. Chronic trigeminal nerve pain, known as trigeminal neuralgia (TN) is the most common cranial neuralgia. Most often the pains can be difficult to block out just by selective attention or stimulating other senses. This particular condition's underlying pathophysiologies are still unknown. Pain has been known to cause multiple issues with structure, function, and quality of life. The debilitating kind can cause deficits in attention, memory, and temperament. This can be demonstrated using fMRI scans that show so and so parts of the brain lighting up when the subject is in pain. One Thai study (Kuvatanasuchati and Leowsrisook 2019) shows prosthodontic dental work, specifically occlusal equilibration as an effective means of reducing the symptoms of TN almost immediately.

A Discussion

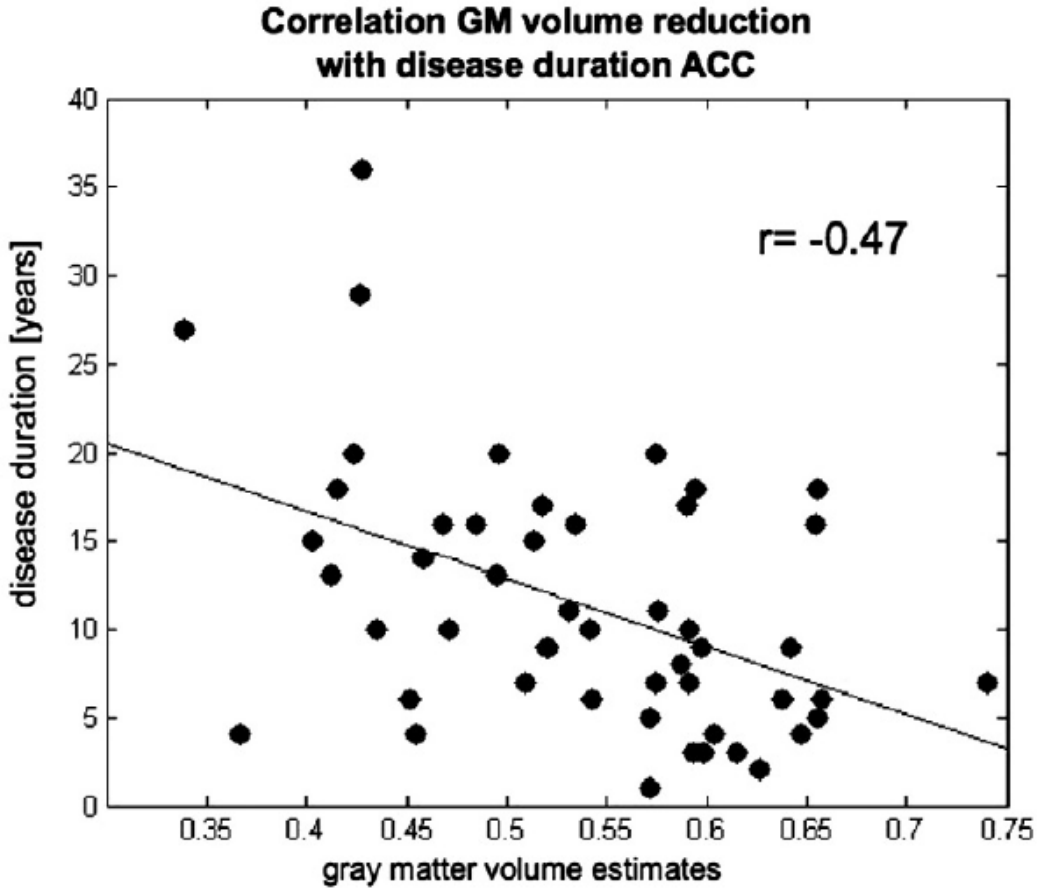
In this paper, we have discussed three significant categories of pain, its sources, and its management. Sweet on pain, distraction on pain, and chronic trigeminal pain. Sweet analgesia is used, in practice, to relieve teething pains in infants. Distraction from pain is time-honoured and can involve music, drink, and laughter. A German study by Obermann et al. has directed our attention to a measurable grey matter volume reduction in patients with chronic TN. More study is needed to determine what sort of cognitive deficits might result from it. Further, it isn't possible with fMRI alone to indicate what sort of GM reduction is involved. One can hope that more research will focus on whether it is reversible (Obermann et al. 2013). Figure 2 shows GM volume reduction correlated with years of TN duration.

Our chemical senses evolved to protect us from environmental hazards and aid in our search for food. The brain identifies a scenario where there is little or

large threat to the holistic well-being of the individual. Pain can have psychological impacts and can affect our cognition through neuronal damage. Pain is not primarily a physical characteristic and can also impact our mental and cognitive health. According to the institute of medicine, the future direction of pain management aims to form precision pain medicine and improvements in clinical education, public and institutional policies and population-level epidemiologic, health services, cognitive sciences, social science, medical informatics, implementation, and other relevant research, informed by clinician/scientist interactions (Mackey 2016).

Figure 2

Regression Analysis of Grey Matter Volume with Disease Duration in Years (r = -0.47, p = 0.006).



Note. Taken from Obermann et al. 2013

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