World Academy of Science, Engineering and Technology
International Journal of Cognitive and Language Sciences
Vol:16, No:04, 2022

A Computational Model of the Thermal Grill Illusion: Simulating the Perceived Pain Using Neuronal Activity in Pain-Sensitive Nerve Fibers

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Abstract : Thermal Grill Illusion (TGI) elicits a strong and often painful sensation of burn when interlacing warm and cold stimuli that are individually non-painful, excites thermoreceptors beneath the skin. Among several theories of TGI, the "disinhibition" theory is the most widely accepted in the literature. According to this theory, TGI is the result of the disinhibition or unmasking of the pain-sensitive HPC (Heat-Pinch-Cold) nerve fibers due to the inhibition of cold-sensitive nerve fibers that are responsible for masking HPC nerve fibers. Although researchers focused on understanding TGI throughexperiments and models, none of them investigated the prediction of TGI pain intensity through a computational model. Furthermore, the comparison of psychophysically perceived TGI intensity with neurophysiological models has not yet been studied. The prediction of pain intensity through a computational model of TGI can help inoptimizing thermal displays and understanding pathological conditions related to temperature perception. The current studyfocuses on developing a computational model to predict the intensity of TGI pain and experimentally observe the perceived TGI pain. The computational model is developed based on the disinhibition theory and by utilizing the existing popular models of warm and cold receptors in the skin. The model aims to predict the neuronal activity of the HPC nerve fibers. With a temperature-controlled thermal grill setup, fifteen participants (ten males and five females) were presented with five temperature differences between warm and cold grills (each repeated three times). All the participants rated the perceived TGI pain sensation on a scale of one to ten. For the range of temperature differences, the experimentally observed perceived intensity of TGI is compared with the neuronal activity of pain-sensitive HPC nerve fibers. The simulation results show a monotonically increasing relationship between the temperature differences and the neuronal activity of the HPC nerve fibers. Moreover, a similar monotonically increasing relationship is experimentally observed between temperature differences and the perceived TGI intensity. This shows the potential comparison of TGI pain intensity observed through the experimental study with the neuronal activity predicted through the model. The proposed model intends to bridge the theoretical understanding of the TGI and the experimental results obtained through psychophysics. Further studies in pain perception are needed to develop a more accurate version of the current model.

Keywords : thermal grill Illusion, computational modelling, simulation, psychophysics, haptics
Conference Title : ICPI 2022 : International Conference on Perceptual Illusions
Conference Location : Boston, United States
Conference Dates : April 21-22, 2022