

## Does pain summation follow arithmetic principles?

Pain is not a simple signal, but a dynamic experience generated by complex activity across multiple regions of the central nervous system. One important yet still poorly understood phenomenon is *spatial summation of pain*. This refers to the fact that the larger the area of the body exposed to noxious stimulation (or the more widespread the injury site is), the stronger the pain feels—even if the intensity of the stimulus at any single point remains unchanged. Imagine holding a cup of hot water: you would instinctively try to grip it using the smallest area of skin possible to reduce the spread and intensity of pain. Understanding this effect is crucial: if summation is too weak, injuries may go undetected; if summation is too strong, pain can become overwhelming, as often observed in patients with chronic pain conditions.

Researchers—including the team from the Laboratory of Pain Research at the Academy of Physical Education in Katowice—predict that spatial summation depends not only on the size and location of the stimulus (injury) but also on how the brain “spreads” the sensation of pain across the body, as well as on neural mechanisms that either amplify or dampen pain. Interestingly, spatial summation *does not seem to follow simple arithmetic rules*: for instance, doubling the stimulated area does not necessarily double the perceived pain intensity. Why this is the case, and what are the underlying mechanisms of summation remain hypothetical, but insights from other sensory systems like vision and hearing could help us better understand how the brain processes pain.

The main goal of this research project is to *comprehensively examine how the nervous system integrates nociceptive stimuli with different spatial properties* and from different sensory modalities. We hypothesize that spatial summation can be described mathematically using models from other scientific fields—such as receptive field models, where each nociceptive neuron has a defined area of activation and inhibition. We will test and extend this model using parameters derived from a thorough quantitative review of the scientific literature (a meta-analysis). Additionally, we will enrich the model using data from two innovative experiments that aim to better understand how pain spreads in the body and how perception works across senses. In one experiment, participants will rate pain caused by simultaneous loud auditory and skin-based electrical stimulation applied to the outer ear. Since these signals travel along entirely different nerve pathways, the study will isolate the brain’s role in combining pain signals. The second experiment will test whether people’s perception of how pain spreads across the body explains summation better than the actual size of the stimulated area. Following the modeling phase, the final part of the project will use machine learning algorithms similar to those used in artificial intelligence to identify hidden nociceptive features that influence spatial summation of pain.

This *project may significantly transform our understanding of how pain arises and which spatial factors influence its intensity*. Most importantly—because of its interdisciplinary nature combining psychophysics, pain research, and neuroscience—this *project has a real chance to push the boundaries of human knowledge regarding how reality is perceived through spatial summation of information from different senses*. Beyond its scientific value, the project also has potential clinical significance: it could lay the groundwork for future clinical studies whose outcomes help predict when and why pain intensifies, and how to effectively limit it in people suffering from chronic pain. The results may serve as a foundation for developing more precise therapies that take into account the spatial aspects of pain and nociception.