**How Fundamentals in Physics Can Explain Perception and Cognition**

Psychophysics is the formal study of perception – our sensory experience of the world. More than 150 years ago, Gustav Fechner defined a percept as the mental event that results from a physical object being analysed by the brain through the detection of specific features.

In the early 20th century, Gestalt psychology took a different perspective. Given that in visual perception, retinal images are two-dimensional whereas in physical and perceptual reality objects are three-dimensional, it was proposed that somehow, the brain must be ‘filling in’ the missing depth information. Gestalt psychologists argue that we perceive everything in its simplest form to create a unified whole out of the information available.

Our prior knowledge of the world is critical for making correct inferences. For example, symmetry occurs throughout the natural world – birds, mammals, fish and insects are all mirror-symmetrical and we know that each half of these creatures looks the same as the other half. The same applies to human-made products – think of chairs, cars and aeroplanes.

Applying a simplicity constraint will almost always lead to the correct interpretation. So, for example, making the very reasonable assumption that one half of a chair will be identical to the other half, means that the percepts that we generate, even with only limited information, will be accurate.

Professor Zygmunt Pizlo at the University of California-Irvine explains that while symmetry is fundamental in both physics and mathematics, it is also fundamental to our understanding of vision.

Of particular interest is the so-called redundancy component of symmetry. Professor Pizlo asks us to consider a wallpaper consisting of a repeating pattern – it could be said that this repetition is redundant because each section of the repeated pattern is the same as the others. But this redundancy, Professor Pizlo explains, is necessary according to our understanding of vision and critically, the perception of three-dimensional objects.

In physics, the concept of symmetry refers to the accepted notion that a law should be invariant – that it does not change even if the conditions of measurement are changed for example, by performing an experiment in two different laboratories. While symmetry has been established as being fundamental to physics for at least a century, it is only in the past decade or so that its potential relevance to psychology and in particular, vision, has been recognised.

According to Emmy Noether’s theorem, every symmetry in nature has an associated conservation law, meaning that specific properties of a measurable entity remain unchanged – or conserved – even when other properties are altered.

Professor Pizlo provides the example of two vehicles involved in a collision. Whilst the vehicles themselves may be damaged beyond repair, one characteristic that is conserved is the total momentum, that is, the product of the mass and velocity of the colliding vehicles. Thus, the conservation of momentum in this case results from the symmetry of the laws of motion.

Professor Pizlo explains how Noether went a step further in demonstrating how conservation laws can be derived by applying a least action principle to symmetries in nature. To put it simply, the least action principle dictates that somehow, the workings of nature are optimal, and that nature works with minimal effort to maximum effect.

Professor Pizlo embraces Noether’s seminal work in arguing that perceptual and cognitive inferences proceed in the same way that the natural laws of physics do. As such, he argues that the mathematical structures of symmetry, least actions and conservations are critical not only to psychophysics but to cognitive science more broadly.

Professor Pizlo further explains that cognitive inferences should be viewed as conservation laws and derived from symmetries characterising the physical and social environment through the application of a simplicity principle. He believes there is much to gain in expanding the existing boundaries of psychology, cognitive science and neuroscience by embracing established fundamentals in physics.