**////Title: How Fundamentals in Physics Can Explain Perception and Cognition**

**////Stand-first**: Professor Zygmunt Pizlo at the University of California-Irvine has advanced degrees in both engineering and psychology. He is drawing on his extensive experience in these often disparate fields to explore how fundamentals in physics can explain how we see the world around us. His novel work extrapolating from the importance of symmetry in physics and the natural world opens up exciting possibilities for psychology and cognitive science.

**////Body text:**

Within the broad field of psychology, psychophysics is the formal study of perception – our sensory experience of the world. More than 150 years ago, Gustav Fechner provided a working definition of a percept as the mental event that results from a physical object being analysed by the brain through the detection of specific and pertinent features such as shape, size and movement.

Gestalt psychology, as it came to the fore during the early decades of the 20th century, took a different perspective on how we perceive the world. Most notably, given that in visual perception, retinal images are two-dimensional whereas in physical and perceptual reality objects are three-dimensional, it is logical to deduce that somehow, the brain must be ‘filling in’ the missing information to create an ‘educated guess’. But how? Gestalt psychologists argue that the person perceives everything in its simplest form to create a unified whole out of the information available.

While it is tempting to assume that having as much information available as possible would lead to more accurate perception, it is our prior knowledge of the natural environment that is critical for making correct inferences. For example, symmetry occurs throughout the natural world, and as such, we know that birds, mammals, fish and insects are all mirror symmetrical. We know that each half of these creatures looks the same as the other half, regardless of whether it is a butterfly, mouse or great white shark. The same applies to human-made products – think of chairs, cars and aeroplanes.

What is important here is that 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 the limited information available, will be good and accurate reflections of reality.

Professor Zygmunt Pizlo at the University of California-Irvine in the USA is building on this new paradigm for psychophysics. He explains that symmetry is fundamental in both physics and mathematics, and proposes that it is also fundamental to our understanding of vision.

Of particular interest is how the so-called redundancy component of symmetry is essential to vision. 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.

Professor Pizlo notes that in the field of physics, the concept of symmetry refers to the accepted notion that a law should be invariant, that is, it does not change even if the conditions of measurement are changed. He points to the example of conducting a physics experiment in one laboratory and then repeating the same experiment in a different laboratory. We would expect that the results should be the same, regardless of where the experiment was conducted.

Importantly, these regularities and certainties across space, time and scenarios, allow scientists to make predictions. Furthermore, they allow scientists to make these predictions using only a small number of rules.

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, the study of vision has been recognised.

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

To explain this important point, Professor Pizlo provides the example of two vehicles involved in a collision. Whilst the vehicles themselves may be damaged beyond repair or recognition, 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. A simple example is that of light, which travels along rays in a straight line taking the least time possible to get from one point to the other.

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.

From this perspective, 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.

If this was to happen, cognitive science would benefit greatly from using the same tools that physicists have been using for over 100 years. This points to an intriguing question – could such an approach lead ultimately to a unified natural science based on symmetries, least actions and conservations? While Professor Pizlo feels that this may be an overly ambitious outcome, he is confident that there is still much to gain in expanding the existing boundaries of psychology, cognitive science and neuroscience by embracing established fundamentals in physics.

According to Professor Pizlo, this expansion will surely include artificial intelligence and robotics. These fields should no longer be merely inspired by cognitive science but should become a part of it. To date, differences in the methodology used by psychologists and computer scientists have prevented them from participating in a real synergy, but the new framework presented by Professor Pizlo offers an exciting pathway for changing it.

This SciPod is a summary of the paper ‘Unifying Physics and Psychophysics on the Basis of Symmetry, Least-Action ≈ Simplicity Principle, and Conservation Laws ≈ Veridicality’, published in The American Journal of Psychology.

For further information, you can visit Professor Pizlo’s web site at UC Irvine or contact him via email.