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Editorial

Editorial of Special Issue "Application of Mathematical Modelling and Symmetry in Neuroscience"

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The first article is "Spectral Clustering Reveals Different Profiles of Central Sensitization in Women with Carpal Tunnel Syndrome (CTS)" [1]. CTS is considered to be one of the most prevalent entrapment neuropathies of the upper extremities. The most common symptoms experienced by CTS patients are sensory disturbances, such as pain, numbness, tingling, and/or paresthesia in areas innervated by the median nerve. This physical condition relates to unemployment and creates substantial health care costs, as well as an economic burden to the concern families. It is estimated that CTS has a lifetime prevalence of 3.1% and an incidence rate of 1.73 per 1000 person-year in the general population; however, the prevalence can reach 10% in middle-aged workers [2–5].

Studies related to CTS and the classification of subgroups of patients with different pain mechanisms can help to provide a better classification of their condition and the development of more adequate therapeutic strategies. However, it is important to note that there is a lack of studies investigating different profiles and subgrouping in individuals with CTS. The only study investigating different profiles in women with CTS identified two groups of individuals, one having hypersensitivity and the other having less sensitivity, using a "predetermined" clinical classification, originally developed for identifying individuals with CTS who were likely to respond positively to physical therapy intervention.

In the scientific literature, spectral clustering (SC) is a technique that has been extensively used in image processing, data mining, and machine learning. It is observed that the results obtained by SC usually outperform other traditional approaches (such as k-means) and they can be efficiently solved using standard linear algebra methods. In this current study, the SC algorithm is used to classify different subgroups of women with CTS, differing in terms of clinical, physical, psychological, and motor variables, to propose different patient profiles. In this study, for the first time, SC identified three subgroups of women with CTS, depending on varying clinical profiles, pain, age, etc. It is expected that the SC algorithm can be used for different neurological disorders, as well as other health related ailments to successfully model them and provide adequate therapeutic strategies to alleviate the suffering of patients.

The second article is "Monte Carlo Simulation of a Modified Chi Distribution Considering Asymmetry in the Generating Functions: Application to the Study of Health-Related Variables" [6]. In nature, it is difficult to find a symmetric distribution. The distributions most commonly observed are asymmetric or skewed distributions. An asymmetric distribution is the one in which the mean does not coincide with the peak of the distribution and one of the tails of the distribution is longer than the other. In practice, skewed distributions describe variable variations in many diverse fields, e.g., biology, social science, health and medicine, ecology, economy, and material sciences. Thus, it is of great interest to use skewed distributions in diverse fields. Many of these variables can be represented by exGaussian functions [7]; however, in practice, they are sometimes considered Gaussian functions when statistical analyses are carried out. Asymmetry in the distribution can play a fundamental role. In this article, using Monte Carlo simulations, the effect of a small asymmetry on the generating functions of the chi distribution is studied. As a practical example to illustrate

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the results of Monte Carlo simulations, three health-related non-dichotomic variables (body mass index, verbal fluency, and short-term memory) were studied. In the future, this methodology can be extended to different fields for a better understanding [8–12].

The third article is “Global Cognitive Functioning versus Controlled Functioning throughout the Stages of Development” [13]. It is known that our response to stimulus can either be automatic or controlled/restricted depending on the nature of the stimulus. Generally, the response that is instantaneous is automatic and activated instantly in a natural way and occurs quite frequently in people of all ages. The neural connections corresponding to these actions are characterized as global and nonspecific; however, a more specific and discriminate mode, which is controlled, is activated only if necessary. This duality of processing of the cognitive system led Adele Diamond to propose the “All or None Hypothesis” [14]. The fundamental difference between the global mode and the selective mode is that the former requires less effort and resources whereas the latter requires a more specific response and voluntary control by inhibiting the predominantly global-command default mode. The “All or None Hypothesis” comprises five corollaries that expose the duality of the cognitive system in various domains and, therefore, allow grouping a large and heterogeneous amount of empirical results. The authors of this article acknowledge that, so far, there are no studies that have contrasted several of these corollaries using the same experimental task and in different evolutionary stages. In addition, there is also insufficient evidence about the distinctive changes and operational characteristics of the selective or controlled processing mode in adolescence. In this sense, much of the studies carried out on the development of the cognitive control function have focused on childhood, adulthood, or old age.

In the present work, the authors analyzed the first three corollaries of the “All or None Hypothesis” in the three stages of human development: childhood, adolescence and adulthood, and stability and change in the controlled mode of functioning during these stages are also explored. The authors conclude that the collective analysis of the three corollaries shows that under conditions that require control and discrimination, children, adolescents, and adults presented a cost that manifested itself in response accuracy and speed. The interest in the detailed study of each corollary lies in the attempt to explain the way people respond under conditions that require cognitive effort. Each corollary involves high-level cognitive functions that allow for the regulation of thought, action, and emotion to achieve goals. The importance of these cognitive functions can be observed in all spheres of life, as well as in day-to-day activities. For this reason, it is emphasized that the study of the controlled mode of functioning is central to cognitive science. In addition, it was found that the controlled and discriminated cognitive system processing mode in adolescents tends to be more accurate and efficient than that of adults and children. Thus, it is suggested that, for a better understanding, further complementary studies in younger cohort are needed in order to exactly determine the point in the developmental timeline at which adulthood begins to show a decrease in the controlled mode of processing.

The fourth article is “Mathematical modeling for Neuropathic Pain: Bayesian Linear Regression and Self-Organizing Maps Applied to Carpal Tunnel Syndrome” [15]. Mathematical modelling of health and medical related problems is prevalent, which directs us to see old problems in a new way and guide us towards finding improved treatments or solutions. Using the Bayesian linear regressions (BLR) method, the authors analyzed the relationship of psychological, physical, and motor variables with pain, function, and symptom severity in female patients suffering from CTS. In addition, to complement the findings of BLR and to develop further insights into the data, the authors propose the use of a self-organizing map (SOM) [16], which is an artificial neural network for clustering and visualizing data in a user-friendly format.

The inspiring results obtained using different mathematical models have potential implications for clinical practice with fewer ambiguities. However, these models have limitations. For example, BLR is a linear model and is unable to capture complex relationships among independent or dependent variables, assuming those were present in the data. In addition, SOM analysis mostly confirmed what was already known. In the future, more-powerful clustering techniques could be employed to divide patients up, depending on different criteria, potentially leading to further insights into the syndrome. However, these results can only be applied to women with CTS and should not be extrapolated to male patients with similar pain conditions. It is expected that further studies investigating gender differences could reveal other associations.

The fifth article is "Simultaneously Spatiospectral Pattern Learning and Contaminated Trial Pruning for Electroencephalography-Based Brain Computer Interface" [17]. Fascinating technological advancements have created a new reality in which we can use electrical signals from brain activity to interact with external devices, called a "brain-computer interface" (BCI). BCI is a computer-based system that acquires brain signals, analyzes them, and translates them into commands that are relayed to an output device to carry out a desired action. Thus, BCI does not use the brain's normal output pathways of peripheral nerves and muscles. There are two types of BCIs based on the electrodes used for measuring the brain activity: non-invasive BCI, where the electrodes are placed on the scalp (e.g., electroencephalography (EEG)-based BCI), and an invasive brain–computer interface where the electrodes are directly attached to the human brain (e.g., BCI based on electrocorticography (ECoG) or intracranial electroencephalography (iEEG)).

An analysis of EEG signals induced by motor imagery (MI), i.e., the imagery of body-part movements, has received considerable attention because of its widespread applications in motor tasks, such as for wheelchairs and mouse cursor controls [18]. EEG signals are easily contaminated by background noise and eye-blink artifacts, which lead to low signal-to-noise ratios. Conversely, EEG signals may be contaminated by improper motor imagery, wherein subjects do not perform the imagery tasks properly, or perform the wrong mental tasks. Data-driven BCI classifiers are sensitive to these noisy and atypical observations. These complexities make decoding of a user's intention difficult. In this study, the authors aimed to design an EEG-based BCI that could automatically eliminate contaminated trials during classifier training, and simultaneously learn spectral and spatial patterns without predefined frequency bands and negative effects from contaminated trials. Inspired by a particle-based approximation technique, this study constructs a filter bank with overlapping frequency bands and detects potential contamination trials that were eliminated during classifier training, which led to improved MI classification accuracy. This study also combines the merits of the particle-based approximation technique and the trial pruning method to simultaneously measure the discriminative power of the frequency band and eliminate contaminated trials. This innovative method overcame the limitation of the trial pruning method that adopted fixed non-overlapping frequency bands and overcame the negative effects of contaminated trials when learning the spectral and spatial patterns.

In the sixth article, "The ⊥-Illusion is not a T-Illusion" [19], variants of the capital Latin letter T were prepared using straight strokes, replaced by J-, C-, or S-curves, mimicking handwritten Ts. These were used to test the hypothesis that overestimation of the length of the T's undivided line, relative to the length of its divided line, may be understood as an adaptation to a corresponding letter schema. The illusion was greater for S-curve Ts than for C- and J-curve Ts, suggesting that approximate bilateral mirror symmetry is more important for the illusion to occur than letterness. Despite the illusion, observers were quite sensitive to the different lengths of the Ts' curves. The author questioned why the upstroke of the capital Latin letter T looks longer than its cross-stroke when both have the same length. This seemingly innocuous question, first posed by the French philosopher Malebranche (1638-1715) [20], has puzzled psychologists for more than a century and is addressed in this work.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Pellicer-Valero, O.J.; Martín-Guerrero, J.D.; Fernández-de-las-Peñas, C.; De-la-Llave-Rincón, A.I.; Rodríguez-Jiménez, J.; Navarro-Pardo, E.; Cigarán-Méndez, M.I. Spectral Clustering Reveals Different Profiles of Central Sensitization in Women with Carpal Tunnel Syndrome. *Symmetry* **2021**, *13*, 1042. [CrossRef]
2. Thiese, M.S.; Gerr, F.; Hegmann, K.T.; Harris-Adamson, C.; Dale, A.M.; Evanoff, B.A.; Eisen, E.A.; Kapellusch, J.; Garg, A.; Burt, S.; et al. Effects of varying case definition on Carpal Tunnel Syndrome prevalence estimates in a pooled cohort. *Arch. Phys. Med. Rehabil.* **2014**, *95*, 2320. [CrossRef] [PubMed]
3. Pourmemari, M.H.; Heliövaara, M.; Viikari-Juntura, E.; Shiri, R. Carpal tunnel release: Lifetime prevalence, annual incidence, and risk factors. *Muscle Nerve* **2018**, *58*, 497. [CrossRef] [PubMed]
4. Epstein, S.; Sparer, E.H.; Tran, B.N.; Ruan, Q.Z.; Dennerlein, J.T.; Singhal, D.; Lee, B.T. Prevalence of Work-Related Musculoskeletal Disorders among Surgeons and Interventionalists: A Systematic Review and Meta-analysis. *JAMA Surg.* **2018**, *153*, e174947. [CrossRef] [PubMed]
5. Dale, A.M.; Harris-Adamson, C.; Rempel, D.; Gerr, F.; Hegmann, K.; Silverstein, B.; Burt, S.; Garg, A.; Kapellusch, J.; Merlino, L.; et al. Prevalence and incidence of carpal tunnel syndrome in US working populations: Pooled analysis of six prospective studies. *Scand. J. Work Environ. Health* **2013**, *39*, 495. [CrossRef] [PubMed]
6. Ortigosa, N.; Orellana-Panchame, M.; Castro-Palacio, J.C.; Fernández de Córdoba, P.; Isidro, J.M. Monte Carlo Simulation of a Modified Chi Distribution Considering Asymmetry in the Generating Functions: Application to the Study of Health-Related Variables. *Symmetry* **2021**, *13*, 924. [CrossRef]
7. Moret-Tatay, C.; Gamermann, D.; Navarro-Pardo, E.; Fernández-de-Córdoba, P. ExGUtils: A Python Package for Statistical Analysis with the ex-Gaussian Probability Density. *Front. Psychol.* **2018**, *9*, 612. [CrossRef]
8. Moret-Tatay, C.; Moreno-Cid, A.; Argimon, I.I.L.; Quarti Irigaray, T.; Szczerbinski, M.; Murphy, M.; Vázquez-Martínez, A.; Vázquez-Molina, J.; Saíz-Mauleón, B.; Navarro-Pardo, E.; et al. The effects of age and emotional valence on recognition memory: An ex-Gaussian components analysis. *Scand. J. Psychol.* **2014**, *55*, 420. [CrossRef] [PubMed]
9. Moret-Tatay, C.; Leth-Steensen, C.; Irigaray, T.Q.; Argimon, I.I.L.; Gamermann, D.; Abad-Tortosa, D.; Oliveira, C.; Sáiz-Mauleón, B.; Vázquez-Martínez, A.; Navarro-Pardo, E.; et al. The Effect of Corrective Feedback on Performance in Basic Cognitive Tasks: An Analysis of RT Components. *Psychol. Belg.* **2016**, *56*, 370. [CrossRef] [PubMed]
10. Meléndez Moral, J.C.; Tomás Miguel, J.M.; Navarro-Pardo, E. An analysis of well-being and age in the elderly. *Rev. Esp. Geriatr. Gerontol.* **2008**, *43*, 90. [CrossRef]
11. Viguer, P.; Meléndez, J.C.; Valencia, S.; Cantero, M.J.; Navarro-Pardo, E. Grandparent-grandchild relationships from the children's perspective: Shared activities and socialization styles. *Span. J. Psychol.* **2010**, *13*, 708. [CrossRef] [PubMed]
12. Castro-Palacio, J.C.; Fernández-de-Córdoba, P.; Isidro, J.M.; Sahu, S.; Navarro-Pardo, E. Human Reaction Times: Linking Individual and Collective Behaviour Through Physics Modeling. *Symmetry* **2021**, *13*, 451. [CrossRef]
13. Introzzi, I.M.; Richard's, M.M.; García-Coni, A.; Aydmune, Y.; Stelzer, F.; Canet-Juric, L.; Zamora, E.V.; Andrés, M.L.; López-Ramón, M.F.; Navarro-Pardo, E. Global Cognitive Functioning versus Controlled Functioning throughout the Stages of Development. *Symmetry* **2020**, *12*, 1952. [CrossRef]
14. Diamond, A. All or none hypothesis: A global-default mode that characterizes the brain and mind. *Dev. Psychol.* **2009**, *45*, 130. [CrossRef] [PubMed]
15. Pellicer-Valero, O.J.; Martín-Guerrero, J.D.; Cigarán-Méndez, M.I.; Écija-Gallardo, C.; Fernández-de-las-Peñas, C.; Navarro-Pardo, E. Mathematical Modeling for Neuropathic Pain: Bayesian Linear Regression and Self-Organizing Maps applied to Carpal Tunnel Syndrome. *Symmetry* **2020**, *12*, 1581. [CrossRef]
16. Kohonen, T. *Self-Organizing Maps*, 3rd ed.; Springer: Berlin/Heidelberg, Germany, 2001.
17. Shieh, C.-P.; Yang, S.-H.; Liu, Y.-S.; Kuo, Y.-T.; Lo, Y.-C.; Kuo, C.-H.; Chen, Y.-Y. Simultaneously Spatiospectral Pattern Learning and Contaminated Trial Pruning for Electroencephalography-Based Brain Computer Interface. *Symmetry* **2020**, *12*, 1387. [CrossRef]
18. Pfurtscheller, G.; Neuper, C. Motor imagery and direct brain-computer communication. *Proc. IEEE* **2001**, *89*, 1123. [CrossRef]
19. Landwehr, K. The ⊥-Illusion is not a T-Illusion. *Symmetry* **2020**, *12*, 1330. [CrossRef]
20. Pastore, N. *Selective History of Theories of Visual Perception: 1650–1950*; Oxford University Press: New York, NY, USA, 1971.