ARTÍCULO DE REVISIÓN

Gac Méd Caracas 2023;131(1):215-221
DOI: 10.47307/GMC.2023.131.1.21

Neuromorphological evidence for Witkin's field-independent cognitive style

Evidencia neuromorfológica del estilo cognitivo independiente del campo de Witkin

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SUMMARY

The visual psychometric Embedded Figures Test classifies people into field-independent and field-dependent cognitive styles. The objectives of this study were to investigate neuromorphological evidence for Witkin's field-independent cognitive style with experimental descriptive studies in subjects with different field-independent cognitive styles and to determine the associated or related underlying neuromorphology. The results demonstrate the existence of neuromorphological bases in the left inferior parietal lobe cortex, which exhibits a pattern of neural connections that are bilaterally related to cortical areas of the inferior frontal gyrus and the anterior and midcingulate cortex. It is proposed that the visual flow presented is not unique due to the limitations of neuroimaging studies and the high variability of the anatomical and histological patterns of the left inferior parietal lobe cortex.

Keywords: *Cognitive style, field independent, inferior parietal lobe.*

RESUMEN

La prueba psicométrica visual de figuras incrustadas clasifica a las personas en estilos cognitivos independientes del campo y dependientes del campo. Los objetivos de este estudio fueron investigar la evidencia neuromorfológica del estilo cognitivo independiente del campo de Witkin con estudios descriptivos experimentales en sujetos con diferentes estilos cognitivos independientes del campo y determinar la neuromorfología subyacente asociada o relacionada. Los resultados demuestran la existencia de bases neuromorfológicas en la corteza del lóbulo parietal inferior izquierdo, que exhibe un patrón de conexiones neuronales que se relacionan bilateralmente con áreas corticales del giro frontal inferior y la corteza cingulada anterior y media. Se plantea que el flujo visual presentado no es único debido a las limitaciones de los estudios de neuroimagen y la alta variabilidad de los patrones anatómicos e histológicos de la corteza del lóbulo parietal inferior izquierdo.

Palabras clave: *Estilo cognitivo, campo independiente, lóbulo parietal inferior.*

DOI: https://doi.org/10.47307/GMC.2023.131.1.21

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Recibido: 25 de septiembre 2022
Aceptado: 3 de enero 2023

INTRODUCTION

In the first half of the twentieth century, psychologists involved in the basic physical sciences created their own theories for the "visual field". These psychologists included Max Wertheimer, who emphasized the perception of movement fields; Kurt Koffka, who emphasized vector fields; and Wolfgang Kohler, who emphasized electric fields. These theories converged in modern German psychology called Gestalt (1). During the development of paradigmatic graphic visual stimuli, Gestalt psychology motivated significant advances in the study of individual differences in perception. One of the most important advances is the Gottschaldt Embedded Figures Test or EFT, where a simple figure is immersed in a more complex one, masking it (1,2). At that time, another psychologist, Louis Leon Thurstone, developed an EFT with topics including mathematical comprehension, language comprehension, and vocabulary to determine the degree of dependence or independence of graphic visual stimuli in problem-solving (1,2). However, as explained by de-Wit and Wagemans, it was Herman Witkin who took advantage of and applied the EFT to examine the cognitive style in people, finding individual differences when people were challenged with the visual task of solving the test (1). According to Witkin, these differences are relatively stable, integrative, and differentiating manifestations in the perception and processing of visual information (3).

According to Witkin, the extent to which a person perceives part of a discrete field within an entire field is defined as being a cognitive style independent of the field or field-independent (FI) and is more analytical, with the ability to see components within a discrete field. This style contrasts with people who have a field-dependent (FD) cognitive style, that is, the ability to see the field as a whole or a more global perception (4).

Witkin initially studied his model in education, searching for the student-teacher academic performance relationship (1-4). He originally concluded that appropriately and according to the dependence or independence of the field, when each individual gravitated towards their topics and careers, their cognitive style contributed to their achievements. As Kozhevnikov et al. (5) noted along with Boccia et al. (6), Witkin's initial studies in education became the first works to reveal individual cognitive differences, with such supporting evidence that Witkin's field dependence-independence (FDI) cognitive styles were standardized for psychometric educational research (7). For example, an early study on task resolution with 103 students from 5 to 11 years old reported that students with an FI cognitive style tended to answer more questions, which increases with age (8). A recent study on the role of FD and FI cognitive styles in the resolution of mathematical problems conducted by Fardin and Radmehr (9) showed that those with an FI cognitive style scored highest on the EFT and remembered the objective of the mathematical problem, analyzed it, and applied mathematical operations to understanding it. Additionally, Guisande et al. (10) contributed knowledge about the role of FDI cognitive styles on mathematical performance and revealed that in the detection of critical signs, such as symbols or letters, children with an FI style are more effective than children with an FI style. Individuals with an FI style tends to focus on partial aspects of the information to be processed, while those with an FD style focus their attention on more global aspects. Finally, and in this same context, elementary school children with an FI style, after mentally reading an algebraic problem, express the question in their language and can draw conclusions based on observations of the facts. They can identify relevant data by planning and writing an equation that they solve and replace it with the relevant data. Children with an FD style, however, make a known aspect of the problem abstract, symbolizing what is known using symbols that are still linked to the context making an equation, which they then solve by creating a list of known and unknown data with a strategy of trial and error (11).

On the other hand, and at the other extreme, it is simultaneously accepted in psychological terms that categorical and dimensional information processing occurs in the brain, supported by neurocortical microstructural asymmetries. This idea is consistent with the histological results of cerebral cortical minicolumns, which are densely packed in the right hemisphere to facilitate categorical processing and less densely packed in the left hemisphere to manage dimensional

information (12). In detail, these neurocortical microstructural asymmetries are initially justified during early postnatal nervous system development by the methylation of individual neuronal DNA. They can generate changes in their own transcriptional activity and in that of other neurons and cortical glia with which they relate, thus shaping their functions, and in turn, are determinants of the dominant methylations in neural circuits that involve large-scale neural epigenomic reconfigurations as individuals age (13).

Therefore, and in this context, it is plausible that neurocortical microstructures observed in the histology of the inferior parietal lobe (IPL) cortex, a recognized center of visual attentional processing of visuospatial tasks (14) with disambiguation activity on Gestalt images (15), may indicate a neurostructural individuality arising from solving visuospatial problems that justify the FI cognitive style described Herman Witkin's classification. The objective of this study was to review neuromorphological evidence from the IPL that emerges from Witkin's FI cognitive style.

MATERIALS AND METHODS

A bibliographic search was carried out in the Web of Science, Scopus, PubMed, and Google Scholar databases using the keywords "cognitive style", "group embedded figures test", "field independence", "field independent", "inferior parietal lobe", "functional magnetic resonance imaging", and "electroencephalography", with the Boolean operators AND, OR, and NOT and dates between 2000 and 2020. The inclusion criteria were articles with a descriptive experimental study that examined the EFT performance in healthy people and, at the other extreme, that examined functional neuromorphology of the IPL. The only exclusion criteria were articles that did not meet the inclusion criteria.

RESULTS AND DISCUSSION

A total of 21 articles were included. When screened with the inclusion and exclusion criteria, nine articles were selected, of which three were descriptive experimental studies of the relationship or direct association of the keywords "field independence", "field independent", or "group embedded figures test" with "functional magnetic resonance imaging".

On the other hand, Hao et al. (16), with a group of 286 healthy students (140 women and 146 men with an average age of 20.01 years, SD = 1.33), analyzed the brain imaging association at rest by nuclear magnetic resonance and amplitude of low-frequency fluctuations (ALFF) in relation to the EFT results (Table 1). The results demonstrated greater cortical cerebral activation in the left IPL and medial prefrontal cortex in FI cognitive style students. Their results led them to claim that the left IPL cortex is recruited in the visuospatial activities of the EFT. However, the results also involve the assumption that because the left IPL cortex is the center of processing of these visuospatial tasks, then the EFT allows the establishment of the tendency to carry out tasks that are more specific to that brain area. Interestingly, focusing on the left IPL, the assumption fits within the neuroanatomical knowledge of visuospatial tasks of the left IPL cortex that Wang et al. (17) functionally focused on in 10 healthy subjects (5 men and 5 women, without reported ages). They demonstrated the existence of a cytoarchitectural morphological diversity for the left IPL cortex beyond the two areas proposed by Brodmann in 1909, BA 39 and BA 40. This finding is justified by the visual attentional coactivity that feeds higher cognitive activities, such as sensory and executive integration of visual memory for recognition and spatial orientation of numerical and arithmetic judgment in reading.

In neurological research scenarios, the works of Klemm et al. (18) provided the first experimental support for the outline of neuroanatomical activity involved in solving the EFT (Table 2). By performing electroencephalograms (EEGs) on seven healthy male students and 10 women of unknown age, they showed that gamma or high-frequency oscillations can be found between electrodes arranged ipsilaterally and contralaterally. These results suggested that a coordinated multicortical neuronal functional state at high frequency can be related to the visual cognitive processing that

Table 1. Descriptive experimental studies of the relationship or direct association of the keywords "field independence", "field independent", or "group embedded figures test" with "functional magnetic resonance imaging" joined by the Boolean operators AND or OR

Authors	Year	Number of people and age	Results
Hao et al. (2013)	2013	286 right-handed people 140 women and 146 men; average age = 20.01 years, SD = 1.33, between 18 and 26 years	Individuals with an FI cognitive style had a greater capacity for local processing and cognitive inhibition. The left IPL could be associated with a greater capacity for specific visual identification
Rajagopalan et al. (2015)	2015	23 right-handed people 12 women and 11 men, between 18 and 31 years	Individuals with an FI cognitive style performed better when observing and detecting a simple figure hidden within a complex figure. The left IPL showed greater activation in individuals with an FI cognitive style who were challenged with searching for and detecting a simple figure hidden within a more complex one.
Walter and Dassonville (2011)	2011	60 right-handed people, 12 women, all aged between 18 and 28 years.	Individuals with an FI cognitive style were more efficient in detecting a simple figure hidden within a more complex one. The inferior left parietal lobe exhibited greater activation in individuals who searched for and located a simple figure hidden in another complex figure.

involves unmasking an image that is immersed in another, more complex image during the EFT.

In fact, Wang et al. (17) studied 10 healthy people *in vivo*, 5 men and 5 women at rest in an age range of 19-25 years, by combining signal processing techniques with a novel spectral algorithm for resonance diffusion. They established the tractography of commissural fibers that emerged from the white matter of the left IPL of six different cytoarchitectonic organizations. Thus, they proposed a parcelled morphofunctional map for the left IPL cortex, including the area called the angular gyrus or Brodmann's area 39, which functionally connects bilaterally with the postcentral gyrus, inferior frontal gyrus, precentral gyrus, midcingulate cortex, inferior frontal gyrus, midcingulate cortex, and anterior cingulate cortex. These connections were reported in a resting state and are like those described by Hao et al. (16) *in vivo* for FI cognitive style individuals established by the EFT. This finding demonstrates that in addition to recruiting the left IPL cortex, the inferior frontal gyrus, medial prefrontal cortex at the anterior cortex of the cingulate, and the same cortex of the midcingulate are recruited. This finding also coincides with the functional studies of Walter and Dassonville (19), who demonstrated with 60 healthy people profiled with the EFT (12 women from 18 to 28 years of age) through nuclear magnetic resonance contrast enhancement that greater blood flow was observed in individuals with an FI cognitive style. The areas of greatest flow were the left PIL cortex, specifically along the inferior parietal sulcus, the cortices of the mid-and anterior cingulate, and the inferior frontal gyrus cortex.

Surprisingly, when tracing the direct cytoarchitecture of the IPL cortex, a descriptive histological work prepared by Caspers et al. (20)

Table 2. Articles with descriptive experimental studies of the relationship or association of the keywords "field independence", "field independent", "group embedded figures test", or "functional magnetic resonance imaging" joined with the Boolean operators AND or OR.

Authors	Year	Number of people and age	Results
Burks et al. (2017)	2017	10 brain images of healthy people, age unknown 54 people, 28 women, with an average age of 24.7, SD 2.07	The left IPL plays a role in left spatial neglect. The FI cognitive style can be fundamental in forming the environmental map, probably due to the greater capacity of people to restructure environmental signals in a global and flexible representation in the long term.
Boccia et al. (2017)	2017	One sample with 242 people (150 women), with an average age of 23.28 years, SD = 1.87, in the age range of 20-30 years.	Individuals with an FI cognitive style was associated with higher intelligence when evaluated with Raven's standard progressive matrix test.
Cuneo et al. (2018)	2018	One sample with 336 people (271 women), with an average age of 21.78 years, SD = 4.07, in the age range of 16-51 years.	
Klemm et al. (2000)	2000	17 people, 7 men, and 10 women, age not reported	Coherence at high EEG frequencies by the binding task of finding a simple figure embedded in the middle of a more complex one and turning off additional independent signal sources to increase the correlation of coherence with the common activity.
Caspers et al. (2006)	2006	10 post-mortem brains (5 men, 5 women between 37 and 86 years old, without a history of neurological or psychiatric disease)	The left IPL had a cytoarchitecture with considerable variability among different individuals, as well as between the left and right hemispheres of the same subject.
Wang et al. (2012)	2012	19 healthy individuals (5 men and 5 women, average age = 22.7 with an age range of 19-25 years)	The left IPL was more architecturally parcelled, with 6 different cytoarchitectural areas with respect to the right IPL, which had 4 areas.

with 10 brains of human corpses (five male, five females, ranging in age from 37 to 86 years, without a history of neurological or psychiatric disease) manifested high interindividual variation. Seven histologically different mosaics were observed, with five on the supramarginal gyrus near AB 40 and two on the marginal gyrus near AB 39. Interestingly, one mosaic was observed histologically where the cytoarchitectures connected with the inferior frontal gyrus and anterior and midcingulate, areas that in turn document links directed at the task of somatosensory spatial discrimination of two points (21).

However, more surprisingly, the low value of the left IPL on functional magnetic resonance images shows that it is activated when individuals classified as FI are challenged to detect complex images embedded and hidden in a real setting (22). Additionally, this activation occurs in the same place where the left IPL literature shows the presence of neurons linked to adaptation and associative learning during human and nonhuman primate development (23).

Fuelling this discussion, a meta-analysis of nuclear magnetic resonance images of left IPL activity during visual perspective tasks for stating

visual identity, according to Arora et al. (24), states that if two people look at different scenes, it is likely that their visual representations differ because they process different scenes with the same common cerebral resource of particular connectivity. This finding reflects a related global network that is functional but also individual, and not because individuals have different visual perspectives of the same scene.

With the neuromorphological background proposed, evidence is introduced that the left IPL underlies visuospatial information processing in the EFT and defines an FI cognitive style, which indicates that as a "trace", individuality is connected with other particular regions. These particularities of visual information streams are presented as a pattern of connections for the reported cognitive style. However, they are not unique and are open to objection due to limited neuroimaging correlation studies, together with a lack of profiling of more healthy subjects by laterality, sex, and broader age groups. Above all, they are not unique due to the variability of the left-right tractographic patterns that start from the IPL (25), together with the histological variability of the same left IPL described by Caspers et al. (20).

CONCLUSION

When solving the EFT visuospatial task and as a neuropsychological result of verification of an FI cognitive style, a neuromorphological relationship can be established based on functional imaging techniques. The left IPL cortex has a greater amount of grey matter, and the commissural neurons of this area generate white matter tracts bilaterally that connect with high probability to the inferior frontal gyrus cortex and the anterior and midcingulate cortices.

Acknowledgments

We thank the PROSEIM research group.

Funding

This research did not receive any type of funding.

Disclosure of interest

The author does not have conflicts of interest of any kind.

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