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Variations of hemispheric functional segregation in the laterality spectrum

Comment on "Phenotypes in hemispheric functional segregation? Perspectives and challenges" by Guy Vingerhoets

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Vingerhoets' article [1] offers a sophisticated and convincing account for the proposal that there are at least three different phenotypes in hemispheric functional segregation. Vingerhoets [1] also points out that only little is known about the relation between different functional asymmetries because almost all laterality studies explore functional asymmetries of a single cognitive function at a time and that there is "only a handful" of studies exploring the lateralisation of two or more functions in the same individuals. Although this is probably more an issue in neuroimaging rather than behavioural studies, it is certainly true that we need more laterality research directly investigating the relationship and dissociation of functional asymmetries between (e.g., verbal vs. non-verbal) and within cognitive domains (e.g., different language functions). In this context it is important to note that being left language dominant (LLD) is not the absence of being right language dominant (RLD). Individuals can be LLD in the articulatory network, sensorimotor interface, and lexical interface, and at the same time they can be RLD or have bilaterally language representation (BLR) for other language functions, such as the spectrotemporal analysis, phonological network and prosody [2].

In my comment I will address three issues. 1. I will question whether we know what a/typical functional lateralisation is. 2. Functional lateralisation is double coded by stable characteristics (traits) *and* temporary, situational aspects (states). 3. The relationship between asymmetry and cognitive performance is not as clear cut as Vingerhoets [1] suggests.

1. What is a/typical language lateralisation?

The term *atypical (language) lateralisation* implies that there is a clear scientific definition of what *typical* (language) lateralisation is and what is not, which is usually defined by strong laterality biases at the population level. Vingerhoets [1] proposed that instead of categorising (or dichotomising) individuals based on hemisphere dominance, it might be more useful to consider the raw distribution of lateralisation indices. Vingerhoets [1] introduced the term "laterality spectrum", which I very much like, but then he concludes that there are three

phenotypes of hemispheric functional segregation, which is not as significant an advance on a dichotomy as the *spectrum* promised. If we consider functional lateralisation as laterality spectrum, which classifies phenotypes on a laterality scale with LLD and RLD as extreme points, it might be insufficient to consider only two (typical, atypical) or three (LLD, RLD, BLR) distinct phenotypes by using arbitrary cut-off scores. This issue is particularly problematic because laterality index (LI)-based cut-offs differ quite substantially across studies, as already pointed out by Vingerhoets [1]. For example, Dietz et al. [3] defined left lateralisation as LI < -.10, whereas Mazoyer et al. [4] applied an LI of < -.50. If we consider functional lateralisation as a genuine spectrum with an infinite number of phenotypes, laterality researchers should probably avoid arbitrary cut-offs and accept that distinct phenotypes of clear hemispheric functional segregation do not exist.

2. Is language lateralisation a trait?

The majority of individuals are right-handed and left lateralised for specific language functions and similar laterality biases at the population level exist for non-human species [5]. Due to the fact that functional asymmetries are a ubiquitous phenomenon that can be quite stable over time, Vingerhoets [1] emphasised that functional lateralisation is a fundamental principle of brain organisation "molded by evolution and genetically blueprinted". However, researchers have tried to fit genetic models to empirical data of handedness and language lateralisation for several decades but only with moderate success, partly because functional asymmetries, such as language lateralisation, are *polygenic* traits.

About half of the variation in asymmetry scores is attributable to individual differences, and although it is widely believed that handedness is one key factor accounting for this, the amount of variance seems relatively similar in right-handers and left-handers [6]. It is over simplistic to consider variation in functional lateralisation simply as "noise". A frequently neglected fact is that functional lateralisation is not static but can dynamically change within relative short-

term periods. Specifically, it has been shown that changes in mood or emotional *state* can affect the degree and sometimes even the direction of "typical" functional asymmetries [7,8]. Dynamic changes in functional lateralisation have also been shown as a consequence of hormonal fluctuations, for example in women during different phases of the menstrual cycle [9].

It has also been shown that functional lateralisation can vary depending on individual cognitive functioning and task demands. For instance, hemispheric functional segregation can be reduced in older individuals [10] and individuals diagnosed with neurodevelopmental and neuropsychiatric disorders [11], probably because the non-dominant hemisphere is significantly more recruited to compensate for neurocognitive deficits. Short-term, *state*-dependent reduction in functional lateralisation have also been shown in younger neurotypical individuals when task demands increase [10,12]. To fully understand functional lateralisation, variation in asymmetries should receive the same amount of attention as invariant aspects of a/typical asymmetries.

3. Is functional lateralisation evolutionarily adaptive?

Vingerhoets [1], as have many before him [5], argues that functional lateralisation must be beneficial and evolutionarily adaptive, given that it is such a ubiquitous phenomenon across species. However, surprisingly few studies have directly investigated the relationship between functional lateralisation and performance. Vingerhoets [1] concluded that "degree, not direction of lateralisation, predicts performance and that absence of clear functional lateralisation results in reduced task performance with BLR individuals performing worse than lateralised participants". In support of this view, Vingerhoets [1] refers to Boles et. al. [13] and Mellet et al. [14]. However, it is important to note that Mellet et al. [14] found no linear correlation between typical LLD and language skills. Depending on the specific lateralised process, Boles et al. [13] even found some negative asymmetry-performance relationships and

suggested that age and maturation of the corpus callosum are relevant factors accounting for variation in the data. Studies showing negative asymmetry-performance relationships challenge simple views of functional lateralisation as being evolutionarily adaptive. There is also evidence of non-linear relationships, with weakly lateralised individuals showing the strongest performance, with the exact optimum of functional lateralisation depending on the specific cognitive domain and individual factors [15,16]. In other words, *"atypical"* functional lateralisation is not necessarily disadvantageous. In fact, atypical lateralisation (i.e., more bilateral recruitment), in elderly people, individuals with mental disorders or simply in less skilled individuals is probably a neuro-compensatory strategy to overcome potential cognitive weaknesses in these individuals. Vingerhoets [1] is right that more research is needed to confirm that atypical lateralisation can be regarded as consequence rather than cause of cognitive weaknesses, not only in cognitively restricted groups but also in the healthy spectrum of individuals of different species. I am also not questioning Vingerhoets [1] proposal that functional lateralisation is adaptive, however, plasticity in functional lateralisation may be as adaptive as functional lateralisation per se.

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