Martin Musálek

Development of Test Batteries for Diagnostics of Motor Laterality Manifestation – Link between Cerebellar Dominance and Hand Performance

KAROLINUM

Development of TestBatteries for Diagnostics of Motor Laterality Manifestation –
Link between Cerebellar Dominance and Hand Performance

Mgr. Martin Musálek, Ph.D.

———

Reviewed by:
prof. Pamela Bryden, Ph.D.
prof. MUDr. Jiří Tichý, DrSc.

From Original Czech Version Translated by Radek Blaheta

Edited by Alena Jirsová
Cover and Layout by Jan Šerých
Typeset by DTP Karolinum Press
First English Edition

ISBN 978-80-246-2285-9
ISBN 978-80-246-2306-1 (online : pdf)

Univerzita Karlova v Praze
Nakladatelství Karolinum 2014

http://www.cupress.cuni.cz

Dedicated to the memory of Prof. Blahuš who taught me the first psychometric steps.

Contents

A unique painting of a left-handed archer, the only in the world, discovered at castle Houska in the Czech Republic

Acknowledgements

A number of individuals contributed significantly to this thesis. First I would like to thank Associate Professor Jitka Chytráčková who supported me during writing the whole monograph. Her approachability and useful lectures were crucial for the final realization of this book. I would also like to thank my special consultant Associate Professor Jan Štochl for his help and recommendations in the field of psychometrics. Sincere appreciations are due to Prof. Frank Danes from University of Puget Sound, to Associate Professor František Véle from Faculty of Physical Education and Sport and František Synek, who gave me invaluable reccommendations and ideas which pushed me beyond my expectation. I would like to especially thank Prof. Jiří Tichý from the Faculty of Medicine for his support and insightful comments on the monograph.

Special recognition and thank is to Prof. Pamela J. Bryden for her patient, great support and constructive criticism an invaluable lectures.

Individuals thank to Dr. Anna Brown from Cambridge, UK for her help and recommendations in the problematic of IRT and SEM.

My family, on the other hand, helped me in more ways than I am capable of expressing. I would like to express my deepest gratitude to my parents and aunt, for their inexhaustible devotion and support. A huge debt of graditude goes to my partner Monika Raczová for being incredibly supportive, understanding and patient.

Last but not least, I am greatful to Theres, Fritz and Anton Kesting and to their friends who were my second family in Canada in Waterloo during my internship where I decided to write this book. Great thanks also to my friends Guaner Rojas and Martin Komarc for their patience in psychometrics discussions.

List of Acronyms

ADHD	Attention Deficit Hyperactivity Disorder
AHPQ	Annett Hand Preference Questionnaire
ANOVA	Analysis of Variance
AP	Absolute Pitch
C	Chance
CCFA	Categorical Confirmatory Factor Analysis
CFA	Confirmatory Factor Analysis
CTT	Classical Test Theory
D	Dextral
DFWT	Dichotic Fused Words Test
DNA	Deoxyribonucleoid Acid
EHI	Edinburgh Handedness Inventory
FA	Fluctuating Asymmetry
IRT	Item Response Theory
LQ	Laterality Quotient
MPA	Minor Physical Asymmetry
MR	Multiple Regression
RS	Right Shift Factor
SEM	Structural Equation Modelling
SRM	Structural Regression Model
WFQ	Waterloo Footedness Questionnaire
WHCT	WatHand Cabinet Test
WHQ	Waterloo Handedness Questionnaire

Aim of this Book

The aim of this book is focused on better understanding of laterality phenomenon and its evaluation. All informations are presented in sense to contribute to the standardization of the new diagnostic tools assessing the motor manifestations of laterality in adolescents and adults aged 18–60 and children aged 8 to 10 years. Both in terms of determining the theoretical concept, the selection of appropriate items, and the verification of structural hypotheses concerning the design of acceptable models. Moreover in this monograph we try to suggest a new approach to assessing of motor laterality manifestation by means of relationship between cerebellar dominance and hand performance.

The first part of this book deals with the concept of laterality, its manifestations and meaning in non-living systems and living organisms. As a human characteristic, laterality is manifested in a variety of functional and structural asymmetries. This part also discusses ways of diagnosing motor manifestations of laterality and the issue of cerebellar dominance, including its reflection in the form of asymmetry of the extinction physiological syndrome of upper limbs.

The second part focuses on the process of the standardization study issues, the present approach of statistical method of structural equation modelling, and the actual design of test battery construction.

The last part of this book presents the results of the structural equation modelling, i.e., the dimensionality and diagnostic quality, including the reliability of various proposed models. All limitations of current research as well as final models and indicators are analysed in the discussion and conclusion of this book.

Keywords: asymmetry, laterality, handedness, cerebellar dominance, structural equation modelling, test development, dimensionality, reliability, kinesiology, motor control

1. Phenomenon Called Laterality

The entire next chapter is devoted to the concept of laterality, its derivation, and the place it holds within both non-living and living systems. All of this information will help us at the end of the chapter to formulate the actual relationship between laterality and humans.

1.1 Laterality as Concept

The basis for the definition of the concept of laterality, derived from the Latin word *latus*, meaning "side" (Kábrt, Kucharský, Schams, Vránek, Wittichová, & Zelinka, 2001), was the finding that most manifestations in living nature result from the spontaneous violation of symmetry. Symmetry is generally considered to be unstable (Coleman, Weinberg, & Lyman Laboratory of Physics, Harvard University, Cambridge, 1973). One of the possible causes of this violation is a loss of symmetry due to a transition from a certain energy state to a lower energy state (for example some symmetry is conserved in a certain energy state, but after the transition to a lower state, this symmetry disappears: spinning flywheel, stopping flywheel). Another case of spontaneous violation of symmetry is violation of parity – sameness. Generally, parity in the field of physics represents the symmetry property of physical quantities or processes under spatial inversion (Riehl, 2010). Spontaneous violation of symmetry leads to the creation of asymmetry (Senjanovic, Mohapatra, & Department of Physics, The City College of the City University of New York, New York, 1975; Viedma, 2007). The word *asymmetry* comes from Greek and refers to irregularity. Asymmetry can even be observed in the basic manifestation of the existence of matter – movement.

1.1.1 Asymmetry in Universe

When it comes to determining the origin of asymmetry in living nature, numerous studies deal with the asymmetry and its manifestations in the universe. Many studies dealing with asymmetry of galaxy spin are currently available. Observation and subsequent simulation studies have been performed, focusing on spiral galaxies that rotate the disk of baryonic matter (composed of protons, electrons, and neutrons). These studies are particularly concerned with the evolution of galaxy spin. In contemporary modern theory dealing with this issue, the "Tidal Torque Theory" model (Schäfer, 2009) is accepted. This assumes that proto-haloes (germs of galaxies) acquire most momentum in the early stage of their development. The perpendicular plane to the disk determines the axis of rotation, while the spiral arms, which are curled inwards, determine the direction of galaxy rotation in most spiral galaxies (Bailin, & Steinmetz, 2005; Porciani, Dekel, & Hoffman, 2002). Spiral galaxies are divided into those that spin clockwise, called "*Z*" galaxies, and those that spin counter-clockwise, called "*S*" galaxies (Sugai, & Iye, 1995). Interestingly, only about 4% of spiral galaxies display the "*S*" character, i.e., counter-clockwise spin (Slosar et al., 2009).

In examining asymmetry in the universe, some studies have also focused on our solar system. Interestingly, seven out of the current eight planets in our solar system orbit the Sun in one direction, and only one (inner planet) Venus goes in the opposite direction. It is also surprising that the actual rotation axis of the outer planet Uranus is situated in the plane of

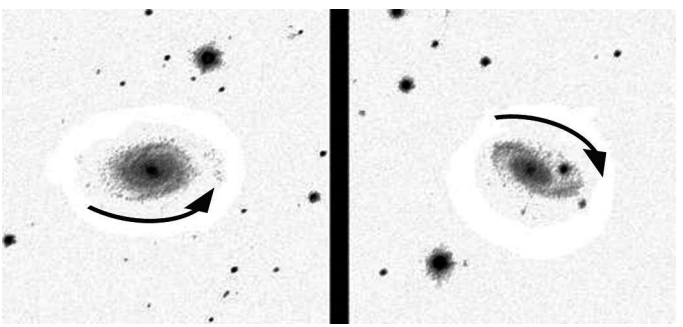

Fig. 1 *S* and *Z* type of galaxy
Galaxy in left field is so called *S* galaxy which is rotating counter-clockwise.
In right field is *Z* galaxy which is rotating clockwise.

Uranus's orbit around the Sun (i.e., the planet is the only one to "roll" on the orbit) (Dones, & Tremaine, 1993). These particularities are explained by interference from other cosmic bodies that have clashed with these planets.

1.1.2 Asymmetry and Chirality in Life System

The issue of asymmetry can also be examined at the microcosm level. Back in the 19th century, while observing the process of grape fermentation under a microscope, the famous French scientist Louis Pasteur discovered that two chemically identical substances can display different effects in the rotation of polarized light. Pasteur found that the acid from the natural fermentation process contains one type of crystal that rotates polarized light clockwise. However, the acid from the industrial fermentation of grapes contained two types of crystals that exhibited mirror uniformity, and did not rotate polarized light. It is also interesting that the acid-containing crystals that rotated polarized light clockwise enabled implemented microorganisms to reproduce and metabolize, while in the second type of acid (containing crystals that rotated polarized light counter-clockwise), microorganisms were not able to start the metabolism. At present, it is known that most molecules in laboratory conditions occur in two forms that are of mirror character (stereoisomer) to each other (Nicolle, 1962). These are also known as chiral molecules (Barron, 1982; Salam & Meath, 1998; Woolley, 1976). The term "chirality" is derived from the Greek word for hand, "*kheir*", and refers to the asymmetry of spatial distribution of an object that is not identical with its mirror image (Riehl, 2010). Although the molecules that make up the earth life organism include human body also occur in two forms in laboratory conditions, the human body always contains only one of them. With respect to saccharides, it is the D-form (dextral), derived from the Latin word for the right side; with regard to amino acids, it is solely the L-form (laevo), derived from the Latin word for the left side. Identification of the side is always based on where the substance rotates polarized light – whether to the right or to the left. This dominance of one type over another is not unique to humans, but applies to most living organisms on our planet (McManus, 2002). The state in which a substance naturally exists in the environment in only one form is called homochirality (Suzuki, Tanaka, Shiro, Shibata, Osaka, & Asahi, 2010).

The current view on the issue of asymmetry formation in biological substances provides two basic hypotheses. One assumes that the original

representation of both forms was roughly the same (i.e., 50%), and that homochirality progressively changed depending on evolution. The second hypothesis is based on the idea that asymmetry leading to homochirality preceded the formation of life and comes from the universe. This hypothesis also has at present time more support *(Origin of Life on Earth: 'Natural' Asymmetry of Biological Molecules May Have Come from Space*, 2011; Breslow, 2011).

Based on the above examples and the outline of the importance of asymmetry and homochirality, viewed from different scientific perspectives, it is evident that these concepts form the basis for the selection of the side or direction in order to obtain certain features or benefits. Chirality clearly shows that due to differences in the spatial arrangement of molecules, two chemically identical compounds display vastly different characteristics. These can be generally termed favourable or unfavourable asymmetry, especially in the context of living organisms.

1.2 Laterality as Characteristic of Human

The important information arising from the previous chapter is that even organic substances – both the basic building blocks of living organisms (amino acids) and the basic units of energy (saccharides) – display chiral asymmetry. As mentioned in the previous chapter, in most cases amino acids occur in living organisms in the L-form and saccharides in the D-form. Due to their specific spatial arrangement, these substances have a certain characteristic. Since the concept of laterality is based on the concepts of asymmetry and chirality, it is possible to view laterality and its manifestations in the human organism as a human characteristic.

This characteristic is likely genetically determined, and some of its aspects are determined during early embryonic development (Wood, 2005). One area in which laterality is manifested (which is explored in detail in humans) is the left-right asymmetry of the arrangement of internal organs according to the vertical axis of the body. Deviations of this left-right asymmetry of internal organs in the form of an inverted arrangement in the abdominal cavity (Guichard et al., 2001; Wood, 2005), called situs inversus (Kosaki & Casey, 1998; Lopez-Garcia & Ross, 2007; Yokoyama, Copeland, Jenkins, Montgomery, Elder, & Overbeek, 1993), have frequently been detected in Kartagener syndrome, whose symptoms include reduced or absent mucus clearance from the lungs and male infertility (Kartagener, 1933). A heterozygous mutation of DNA/1 gene,

which according to scientists is linked to a change in the asymmetry of internal organs, has been found in the genetic code of patients with Kartagener syndrome (Failly et al., 2009; Guichard et al., 2001; Leigh et al., 2009). Among other things, the change in this asymmetry may also lead to severe congenital defects affecting mainly the cardiovascular system. Some authors argue that gene mutations may cause changes in several aspects of chirality, which may in turn lead to situs inversus (Oliverio, Digilio, Versacci, Dallapiccola, & Marino, 2010). Despite the fact that laterality is a genetically determined human characteristic that displays more stable personality traits, it is important to realize that it does not have absolute stability over lifespan. Laterality is influenced by various environmental factors that may affect its form, even in the early postnatal period (Alibejk, & Angaji, 2010; Bakan, 1978; Elliot, & Roy, 1996; McManus, 1981; Orsini, & Satz, 1986).

As can be seen, laterality, as a human characteristic, plays a very important role in the own existence of humans. Therefore, the next chapter will focus on the most complex system known to us in which individual structural asymmetries are directly reflected in the external motor manifestations of humans: the human brain.

2. Human Brain

The human brain is currently the most complex system known to us that has a certain structure and very specifically differentiated functional centres. Damage to the brain results in a temporary or permanent loss of certain functions. Brain research and issues related to the exploration of asymmetry and laterality have been studied for many years. For instance the relationship between speech and a particular area of the brain was discovered by Pierre Paul Broca as early as in the 19th century.

2.1 Structural Hemispheric Asymmetry

This section deals with the issue of structural asymmetry of cerebral hemispheres related to motor activity and motor manifestations of laterality. The following information is based on current approaches to the assessment of brain structure.

Starting from the subcortical area of diencephalon, the brain displays a paired arrangement of its individual parts: the right and left part of the thalamus (Sherman, & Guillery, 2000), and the right and left half of the hypothalamus (Swaab, 2003). The cortical area is divided into two functionally distinct hemispheres (left and right), which are divided by a longitudinal fissure, and which communicate with each other through the corpus callosum. Since the function is superior to the organ, the most significant structural differences in the human brain are demonstrated by lateralization in cortical areas of the telencephalon.

Basic human brain asymmetry is evident at a glance. The right hemisphere is mostly wider than the left hemisphere in the frontal region. In addition, the right anterior frontal region is larger than the same region of the left hemisphere. By contrast, the occipital region is wider in the