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The Role of Hemispheric Preference in Student Misconceptions in Biology

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Abstract: The various intuitive reasoning types in many cases comprise the core of students' misconceptions about concepts, procedures and phenomena that pertain to natural sciences. Some researchers support the existence of a relatively closer connection between the right hemisphere and intuitive thought, mainly due to a notably closer relation of individual intuitive cognitive processes with specific right hemisphere regions. It has been suggested that individuals show a different preference in making use of each hemisphere's cognitive capacity, a tendency which has been termed Hemisphericity or Hemisphere Preference. The purpose of the present study was to examine the association between hemispheric preference and students' misconceptions. A correlational explanatory research approach was implemented involving 100 seventh grade students from a public secondary school. Participants completed a hemispheric preference test and a misconceptions documentation tool. The results revealed that there wasn't any differentiation in the mean score of misconceptions among the students with right hemispheric dominance and those with left hemispheric dominance. These findings imply a number of things: (a) the potential types of intuitive processes, that might be activated by the students, in interpreting the biology procedures and phenomena and their total resultant effect on students' answers, probably do not have any deep connection with the right hemisphere; (b) it is also possible that students might use reflective and analytic thought more frequently than we would have expected.

Keywords: *Biology concepts, hemispheric preference, intuitive reasoning, right hemisphere, students' misconceptions.*

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Introduction

In our daily lives we often rely on intuitive reasoning in order to make sense of the world around us and despite the trust we show to our intuition, it is possible that we might be led to biased and suboptimal judgments (Lieberman, 2000). Many researchers have highlighted the importance of implicit reasoning processes, which unconsciously affect students' thinking in the attempt to interpret various natural phenomena in their everyday lives, to solve problems and to answer questions in academic tests (Fischbein, 2002; Maeyer & Talanquer, 2010; Vosniadou, 1994).

The various intuitive reasoning types in many cases comprise the core of students' alternative concepts and explanations about procedures and phenomena that pertain to natural sciences (Arenson & Coley, 2018; Carey, 1985; Coley et al., 2017; Hatano & Inagaki, 1994, 2000; Inagaki & Hatano, 2006; Kelemen, 2012). Coley and Tanner (2012) refer to the aforementioned intuitive judgments as cognitive construals, meaning an intuitive way of thinking which might be a set of assumptions, a type of explanation, or a predisposition to a particular type of reasoning. Construal-based reasoning has been positively associated with the prevalence of misconceptions that students hold in the field of biology (Coley & Tanner, 2015).

Various intuitive construals have been identified with respect to knowledge domain or scientific field, conceptual context, the type of process that is being performed at a specific time and have been referred to as heuristic reasoning (Fischbein, 2002; Kahneman, 2011; Kryjevskaia et al., 2014; Maeyer & Talanquer, 2010), intuitive rules (Osman & Stavy, 2006; Stavy & Tirosh, 2000), intuitive thought or intuitive theories (Arenson & Coley, 2018; Carey, 1985; Coley et

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al., 2017; Hatano & Inagaki, 1994, 2000; Kelemen, 2012), implicit assumptions, (Hatano & Inagaki, 2000; Vosniadou, 1994) phenomenological primitives (diSessa, 1993).

Hemispheric asymmetry has been a widely accepted principle of the brain organization where numerus networks serve different functions and are differentially lateralized (Corballis & Häberling, 2017; Gazzaniga et al., 2014). The increasing collection of various data as a consequence of the modern instruments complexity and high fidelity that are used, has renewed the interest of many researchers for the subject of hemispheric preference (Morton et al., 2014). Extensive research supports the fact that human reasoning relies on various procedures, whose neural loci are to a great extent lateralized to either right or left-brain hemispheres. As a consequence, this causes each hemisphere to operate on different principles, which in turn affect human reasoning in a different way (Turner et al., 2015).

The idea that different ways of thinking and behavior are specialized, to a significant extent, in the function of one or the other cerebral hemisphere, as well as the different preferences between individuals in using the cognitive potential of each hemisphere, has been defined as hemisphericity (Bogen, 1969) or hemispheric preference (Zenhausern, 1978). Individuals that are left-brain dominants rely more on processing information with the left hemisphere and tend to show an analytic, sequential mode of reasoning, relying preferably on verbal–abstract representation. On the contrary, individuals that are right-brain dominants tend to present an intuitive, holistic, synthesized and visual-motor way of processing information and reasoning (Díaz-Morales & Escribano Barreno, 2014; Oxford, 1995).

The association between the right hemisphere and intuitive thought was proposed many decades ago (Ornstein, 1977), although it was considered fairly speculative due to restricted and deficient scientific evidence (Gardner, 1978). However, more recently, some researchers support the existence of a relatively closer connection between the right hemisphere and intuitive thought, mainly due to a notably closer relation of the individual intuitive cognitive processes with specific right hemisphere regions (Marks-Tarlow, 2014; Schore, 2010).

Intuition is characterized by automatic, associative, unconscious processing and implicit thought and is associated with the function of nonverbal decoding of the right hemisphere (Dörfler & Ackermann, 2012; Evans, 2010; McCrea, 2010). Research findings suggest that intuitive judgments rely on preexisting knowledge, which may lead to decisions without being consciously retrieved (Bolte & Goschke, 2008; Bowden & Beeman, 1998). Neuroimaging studies indicate the subconscious activation of remote associates in semantic memory that are predominantly associated with the right-hemispheric processes (Ilg et al., 2007). In an extensive review, Happaney et al. (2004) underline the link between the right hemisphere and the implicit process of information, indicating concurrently a particular dexterity of the right hemisphere in involving itself with procedures that concern decision-making.

As it was mentioned, various intuitive modes of reasoning are involved in the generation of students' misconceptions affecting their comprehension about scientific phenomena as well as their way of learning in general. On the other hand, the existence of a relative individual connection of intuitive thought, with the right cerebral hemisphere, could be reflected on a differential presence of misconceptions among students with different hemispheric preference. Heretofore, there has not been any research approach focusing on the study of students' misconceptions as a result of their intuitive reasoning in relation to both the relative specialization of the two brain hemispheres in specific cognitive procedures and the differences in students' predilection for them. The purpose of the present study was to examine the link between hemispheric preferences and students' misconceptions. Based on the theoretical approaches and the studies mentioned above, our hypothesis was that, students with the right hemispheric preference, due to a more intuitive type of reasoning, might be expected to have a relatively larger number of misconceptions than students with the left hemispheric preference. In brief, it could be assumed that the formation of various misconceptions, generally as a product of intuitive reasoning, would possibly be differentiated among students with right or left hemispheric preferences.

Methodology

Research Design

The present research was based on a correlational explanatory approach and more specifically, on the relation between the number of students' misconceptions in specific biology conceptions. To this end, their type of hemispheric preference was examined.

Sample and Data Collection

A total of 100 seventh grade students, 56 male and 44 female, (aged 12-13 years, M = 12.47 years, SD = 0.30 years) from a public mainstream school in Athens Greece, participated in this study. A convenience sampling approach was employed, as the researcher was an active teacher in the school and there was sample availability (Cohen et al., 2007; Creswell, 2012).

Students' intuitive thinking assessment was carried out through the documentation of their misconceptions in biology concepts and various procedures deriving from different units included in the Junior High School first grade teaching material. It should be stressed that, for the purpose of our study, we have considered as an integrated whole all the individual modes of intuitive reasoning that were described in the introduction and might be activated, determining students' answers in various questions concerning natural sciences.

An assessment tool was appropriately formed by including elements from other related tools that were used in previous studies with a similar way for probing students' intuitive thought (Coley et al., 2017; Coley & Tanner, 2015; Kelemen et al., 2012; Shtulman & Harrington, 2015). It was structured based on Tamir's (1971) approach consisting of 12 multiple choice items with three alternative answers, one of which was scientifically correct and the remaining two were the distractors. Each distractor consisted of a statement which was referring to a common student misconception about biology concepts and procedures (e.g., cell circulatory system, living organism), identified in previous studies (American Association for the Advancement of Science [AAAS], 2014; Arnaudin & Mintzes, 1985; Driver et al., 2014; Ebel & Frisbie, 1991; Inagaki & Hatano, 2006; Köse, 2008; Lee & Diong, 1999; Mann & Treagust, 2010; Morris et al., 2000; Stavy & Tirosh, 2000; Tamir, 1990) ensuring in parallel the validity and reliability of the instrument. The scientifically adequate response of each multiple choice scored with 1 point and each biology misconception statement scored with 0. The maximum score of the instrument, if all responses were correct, would amount to 12 points.

Students' hemispheric preference was assessed using the Preference Test (PT), a 20-item self-report instrument created by Zenhausern (1978). PT comprises an adequate instrument for the hemispheric preference assessment in adolescents (Díaz-Morales & Escribano Barreno, 2014; Vlachos et al., 2013). Ten items are presumably related to a left-hemisphere mode of thinking (e.g., ''I find it easy to think of synonyms for words'') and 10 items presumably refer to a right-hemisphere mode of thinking (e.g., ''I have a good sense of direction''). Participants use 10-point scales to indicate the extent to which the items apply to them (ranging from 1 = ''not at all''/ ''never'' to 10 = ''very much''/''always''). To obtain an index of hemisphere preferences (total PT), the sum of the right brain-oriented answer scores was subtracted from that of the left brain oriented answers to produce a hemisphericity index (-100 to +100). Thus, a positive difference score is taken as an indication of a stronger preference for right-hemisphere cognitions, whereas a negative difference score is interpreted as a stronger reliance on left-hemisphere cognitions. A score of zero indicated individuals with no clear preference to the right or the left hemisphere (whole brain dominance). PT has been found to have acceptable psychometric properties (Merckelbach et al., 1996) and correlates with biophysical measures of hemisphericity (Merckelbach et al., 1997). Merckelbach et al. (1996) found the PT to have sufficient test–retest stability and internal consistency, acceptable variability and a two factor structure consistent with a left and right preference model. Additionally, Merckelbach et al. (1997) found that subjects who present a right hemispheric preference on the PT display greater alpha power over the left midfrontal area during resting electroectroencephalogram (EEG). Because higher alfa levels are associated with lower levels of activation, this asymmetry is interpreted as indicative of a greater right hemispheric activity (Hellige, 1993). In a subsequent study (Russo et al., 2001) researchers confirmed the correlation between PT scores and midfrontal EEG asymmetries. The completion of both PT (Zenhausern, 1978) and the misconception documentation tool, took place during the first teaching period at the beginning of the school year.

Data Analysis

The data were statistically analyzed using IMB-SPSS version 25.0. A descriptive analysis was applied calculating the hemispheric preference groups distribution (frequencies) of the sample as well as means, standard deviations, maximum and minimum of the misconceptions scores for each hemispheric group separately. A Shapiro-Wilk test (Table 1) showed that data were conformed to normal distribution ($p>0.05$). The possible relation between hemispheric preference and number of student's misconceptions was examined. A t-test was applied to compare the mean number of students' misconceptions between the two different hemispheric groups (right- left). Additionally, a chi-square test was applied to further examine a potential relation between hemispheric preference and number of students' misconceptions.

Table 1. Test of Normality

Hemispheric Preference	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Right	.946	36	.078
Left	.964	60	.072

Findings / Results

On the basis of the PT scores, which were calculated as described above, students were assigned to a left hemisphere preference group, a right-hemisphere preference group and a whole-brain dominance group. The distribution of the three main brain dominant categories totally, in the sample, were 60 or 60% left-brain dominants, 36 or 36% right-brain dominants and 4 or 4% whole-brain dominants (Figure 1). Our findings are in accordance with previous studies at which the same tool had been used for assessing hemispheric preference in secondary school students (Vlachos et al., 2013).

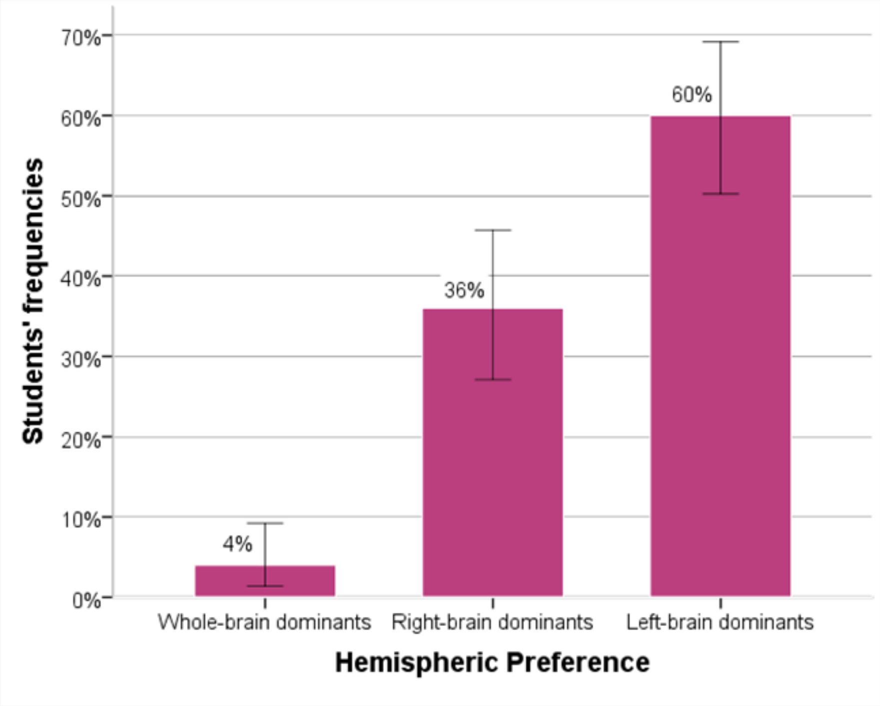

Figure 1. Students' Percentage Distribution per Brain Dominant Group.

The maximum and lower number of misconceptions along with the mean score that students of each brain dominant group (left – right) displayed is presented in Table 2. The mean number of students' misconceptions between the right–hemisphere preference (5.92) and the left hemisphere preference (6.47) groups were compared using an independent sample t-test. The results showed that there was not a statistical difference between them ($t=1.44$, $p > 0.05$, 2-tailed).

Table 2. Comparison of Students' Mean Scores on the Misconceptions Tool among Right and Left-Brain Dominant Groups.

Hemispheric Preference	N	max	min	Mean	SD	t	df	p
Right	36	1	9	5.92	1.59	1.44	94	0.15
Left	60	1	10	6.47	1.93			

We further explored the connection between hemispheric preference and the number of students' misconceptions by grouping the values of the misconceptions' documentation tool in three conventionally distinct qualitative categories: "few", "several" and "many". Specifically, the category "few" included the number of misconceptions from 1 to 4, the category "several" from 5 to 7, and the category "many" from 8 to 10. In that way, students were assigned to the appropriate category, according to the number of misconceptions noted in the documentation tool.

Students' distribution in the three categories mentioned above, for each hemisphere preference group, is shown in Table 3. The cross-tabulation of hemispheric preference groups with the misconceptions categories showed that there was not a statistically significant relationship between them ($x^2 = 2.95$ $df = 2$, $p > 0.05$), indicating that the differences on the misconceptions frequencies between the two hemispheric preference groups were not significant.

Table 3. Students' Number Frequencies among the Three Misconceptions Categories per Brain Dominant Group (right-left).

	Misconceptions categories					
	few		several		many	
Hemispheric Preference	N	f(%)	N	f(%)	N	f(%)
Right	5	13.9	25	69.4	6	16.7
Left	9	15.0	32	53.3	19	31.7

Discussion

In the present study the association between misconceptions, as origin of intuitive reasoning, and the students' different hemispheric preference were examined. The hypothesis was that students with right-hemisphere preferences would display more misconceptions than those with left hemisphere preferences, as the intuitive nonconscious reasoning processes and intuitive notions that underlie, have been referred by some researchers to be associated predominantly, but not absolute, with various loci of the right hemisphere (Bolte & Goschke, 2005; Marks-Tarlow, 2014; Schore, 2010).

The results indicated that there wasn't any differentiation in the mean number of misconceptions among the students with right hemispheric dominance and those with left hemispheric dominance. Additionally, the frequencies of students that observed few, several, or many misconceptions were not also significantly different between the two groups of hemispheric preference (right-left). Our findings don't seem to be in accordance with the above previous studies which support the connection between the right hemisphere and intuitive thought (Marks-Tarlow, 2014; Schore, 2010). Although the association between individual intuitive cognitive processes and specific right hemisphere regions has been supported by some researchers (Happaney et al., 2004), as it was revealed from our study, there doesn't seem to be a corresponding relation between the right hemisphere and the various intuitive reasoning types which constitute factors that generate misconceptions.

Students' reasoning mechanisms that are being activated during the elaboration and interpretation of biology concepts and processes are of great importance for the expression of misconceptions as false answers (Heckler, 2011). Intuitive models of thought, in many cases, interfere in students' reasoning either determining their answers in various tasks (Shtulman & Harrington, 2015) or consisting the core for creating misconceptions concerning concepts and phenomena of Biology sciences (Arenson & Coley, 2018; Carey, 1985; Coley et al., 2017; Hatano & Inagaki, 1994, 2000; Kelemen, 2012). In an extensive review, including many neuroscience fields about the orbitofrontal cortex, Happaney et al. (2004) point out the connection between the right hemisphere and the implicit information process, underlining concurrently its special cognitive skill regarding decision-making in everyday experiences. Intuitive thought is an automatic, nonconscious, implicit process associated with the operation of right hemisphere nonverbal decoding mechanisms (McCrea, 2010). According to the dual system theory, intuitive thought is a Type 1 cognitive process generally characterized by processing that is fast, associative, and biased (Dane & Pratt, 2009; Dörfler & Ackermann, 2012; Evans, 2010).

As it was revealed by the present study, the degree of intuitive thought that was possibly used by the students in answering the instrument items, according to the number of misconceptions that they noted, didn't have any significant difference between students with right or left hemispheric preference. This fact suggests that probably the potential intuitive processes that were activated by the students, in interpreting the various biology phenomena, might not have had any special connection with the right hemisphere. Yet, it could be a conjunction of different reasoning and cognitive mechanisms that equally activate various brain regions and it is hard to be attributed to a higher or lesser extent to any of the two hemispheres. However, the case that some kind of intuitive thought could have led to the right choice or answer can't be excluded. Secondly, the use by the students of Type 2 processes, that involve reflective and analytic thought, especially when there isn't time pressure, it is possible to occur for the choice of an answer (Evans, 2010).

Furthermore, although the various cognitive mechanisms, that are being involved in the generation of students' misconceptions, have been characterized as intuitive, they display a relative heterogeneity associated with the scientific field, the conceptual context that is being activated and the kind of task that is being performed at the exact moment. As a consequence, they constitute a whole of different types of intuitive reasoning that have been documented, as it has been mentioned, with various terms (Arenson & Coley, 2018; Carey, 1985; Coley et al., 2017; Fischbein, 2002; Hatano & Inagaki, 1994, 2000; Kelemen, 2012; Kryjevskaia et al., 2014; Maeyer & Talanquer, 2010; Osman & Stavy, 2006; Stavy & Tirosh, 2000). This means that the various intuitive modes of thinking might also differ both in their individual processes and in the different situations and questions that their activation occurs, causing multiple effects on students' answers. This fact may suggest that their total resultant effect probably does not exhibit any deepest association with the right hemisphere, at least as it has been attributed to the intuition as a broader cognitive process (Marks-Tarlow, 2014; Schore, 2010). This could be another reason why there was not any statistically significant differentiation in the misconception's presence among the students with right or left hemispheric preference.

Research has indicated that even though different individuals are expected to develop similar implicit intuitive judgments and heuristic reasoning in a specific science field, however it is possible that they can use them in a different manner in any case, depending on their previous knowledge, their experiences, and the context of the task that they attempt to perform (Siegler & Crowley, 1994; Talanquer, 2009).

Conclusion

In the present research approach, the attempt of studying neuroscientific findings, concerning intuitive cognitive reasoning procedures and their relative differentiations in the function and the use of the two cerebral hemisphere in conjunction with their involvement in the creation of students' misconceptions, could provide valuable insights into the meaningful understanding of the phenomenon of misconceptions and its effect on students' learning. Heckler (2011) emphasizes that such research approaches and models of causal processes examination, might subserve the formation of predictions of how students would respond to specific instruction methods. This in turn could contribute to the designing of teaching methods that would enable students to a better scientific concepts apprehension. Concurrently, teachers would be informed for the need of adapting instruction by enriching it with various teaching practices that fit to the different types of students' brain hemispheric preference.

In the case of our study, the examination of the link between hemispheric preference and students' misconceptions showed that there wasn't any differentiation in the mean number of misconceptions among the students with right hemispheric dominance and those with left hemispheric dominance. This could denote that various differentiated instructional approaches might have the same effects on students' attempts with different hemispheric preference to cope with scientific misconceptions, although this case might need further research.

Recommendations

The assessment of students' hemispheric preference was conducted by using only one instrument. Therefore, it is critical to conduct the same research study using more precise methods in the assessment of hemispheric preference in order to reaffirm and generalize the findings. For example, noninvasive and relatively inexpensive techniques such as functional transcranial Doppler ultrasonography (fTCD), that have been shown to be a reliable method for determining cerebral lateralization of function (Deppe et al., 2004), could be used in future studies to examine the association between hemispheric preference and students' misconceptions explicitly. In addition, further studies could investigate the association of students' hemispheric preference separately with each distinct type of intuitive construal for the purpose of having the factor of intuitive reasoning heterogeneity limited and possibly giving a clearest insight of the two aforementioned variables relation.

Limitations

The present study has some limitations which do not allow us to have a clearer picture of the association between hemispheric preference and students' misconceptions. Although our initial design was to assess students' hemispheric preference in several ways, it was done using only one instrument. This happened because we found insurmountable difficulties in having students visit the laboratory, in order for additional assessments of cerebral laterality to be carried out. In addition, the limited time available for completing the questionnaires in school in general, in order to avoid any deviation from the teaching material schedule set by the curriculum, did not allow us to administer more questionnaires.

Authorship Contribution Statement

Lagoudakis: Conceptualization, design, analysis, writing, final approval. Vlachos: Conceptualization, design, analysis, supervision, editing/reviewing. Christidou: Supervision, design, editing/reviewing. Vavougios: Supervision, design, editing/reviewing. Batsila: Editing/reviewing.

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