STUDIA DOCTORALIA
PSYCHOLOGY AND EDUCATIONAL SCIENCE

UNIVERSITY OF BUCHAREST
VIRTUTE ET SAPIENTIA

Testing the HERA Model for Episodic Memory in a Sample of Students

Alina Chiracu, Cristian Buică-Belciu

University of Bucharest

ARTICLE INFO

Article history:
Received 24-January-2024
Accepted 28-April-2024
Available online 01-May-2023

This article should be cited as: Chiracu, A., Buică-Belciu, C. (2024). Testing the HERA Model for Episodic Memory in a Sample of Students. *Studia Doctoralia. Psychology and Educational Science, 15*(1), 46-54. https://doi.org/10.47040/sdpsych.v15i1.172

This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Corresponding author at: University of Bucharest, Department of Psychology, 90 Panduri Av, Bucharest, RO. Tel.: +40 (0) 31-425.34.45.
E-mail address: alina.chiracu@fpse.unibuc.com

ABSTRACT

The aim of this study is to test Hemispheric Encoding/Retrieval Asymmetry model – HERA for episodic memory in a sample of students. A number of 64 right-handed students participated in the study, aged between 18 and 47 years (M = 20.66, SD = 4.84), 62 females (97%). Laterality was measured with Edinburgh Handedness Inventory and only right-handed students were included (with right laterality quotient ranging between 75 and 100, M = 99.92, SD = 4.38). The experimental design was inspired by the study of Propper et al. (2013). Participants were randomly assigned in one of the five conditions. Memory stimuli consisted of a list of 36 words and clenching stimuli consisted of 5 cm diameter rubber balls. It was hypothesized that right hand clenching (left hemisphere activation) pre-encoding and left hand clenching (right hemisphere activation) pre-recall, would result in superior episodic memory. One way ANOVA and Fisher LSD post hoc test were performed. Results supported the HERA model.

Keywords: *HERA model, episodic memory, hand clenching, word stimuli*

1. INTRODUCTION

Memory is one of the most fascinating human cognitive processes. Its study has interested numerous authors over time, proposing a series of theories and proving empirically and through functional neuroimaging that there are several types of memory and several ways of activating the brain circuits responsible for them. Episodic memory is a complex set of human cognitive processes that allow the encoding, storage and intentional recollection (retrieval) of unique events associated with the context in which they occurred (Baddeley et al., 2001). Wheeler et al. (1997), in an attempt to clarify this concept, established two distinct directions for defining episodic memory. The first refers to memory that renders possible conscious recollection of personal happenings and events from one's personal past and mental projection of anticipated events into one's subjective future. The second refers to a type of memory task and to performance on the task. Episodic memory in this sense refers to the acquisition of propositional information on a particular occasion (declarative, cognitive, or symbolically representable) and its retreval on a subsequent occasion. The typical laboratory list-learning task in which participants are exposed to a collection of verbal items and then tested for what they have learned by recall, recognition, or some kind of memory judgment is often classified as an episodic memory test (Wheeler et al., 1997).

In the present study we aim to investigate episodic memory in the second definition of the term.

The role of the cerebral hemispheres in memory processes

It is already well known that the two cerebral hemispheres do not contribute equally to cognitive activities (Gazzaniga, 2000). The best example of hemispheric asymmetry is language, with the left hemisphere being significantly more involved than the right hemisphere. In neuroscience, memory is defined as a combination of three components: encoding, storage and retrieval. Previous studies have shown that there are differences in the contribution of the two hemispheres to certain memory processes. Despite the anatomical and physiological similarity of the two cerebral hemispheres, they have different information processing capabilities. These differences are found in the nature of the perceptual information that each hemisphere processes preferentially or in striking asymmetries for higher cognitive functions (Hellige, 1993). The different patterns of sensory analysis and the subsequent selection of responses suggest that the two brain hemispheres differ fundamentally in the records they retain of an experience, differences that are reflected in the way memory is processed. While left prefrontal cortex (PFC) is more involved in encoding, right PFC is more involved in retrieval (Ward, 2015). Thus, during learning a new material (encoding), the left PFC tends to be more active than the right PFC, while during recall or recognition (retrieval), the right PFC tends to be more active than the left PFC. This pattern of operation has been called the Hemispheric Encoding/Retrieval Asymmetry model (HERA) (Tulving et al., 1994). Although there were studies that reported exceptions to the HERA pattern, numerous others, based on positron emission tomography (PET) or functional magnetic resonance imaging (fMRI), confirmed the existence of the general HERA pattern (Cabeza & Nyberg, 2000; Fletcher & Henson, 2001), respectively a higher involvement of left PFC in cognitive tasks.

Activation of contralateral cerebral hemispheres through hand contraction

Contraction of the right or left hand leads to increased neural activity in the frontal lobe of the contralateral hemisphere (Harmon-Jones, 2006; Peterson et al., 2008). Electroencephalographic (EEG) reports have shown that left hand clenching for about 90 seconds increases right hemisphere activity, and right hand clenching increases left hemisphere activity. In a study on the effects of hand contraction on the persistence of hemispheric asymmetry, Beckman et al. (2013) showed through EEG that athletes who grip a ball in their left hand immediately before starting their sports activity did not show performance deterioration under severe pressure, a phenomenon determined by priming of the dominant right hemisphere. Hirao and Masaki (2019) also showed that squeezing a ball harder for a long period will lead to stronger asymmetrical activity by increasing the activation of motor-related areas. Hoskens et al. (2020) demonstrated the activation of the contralateral cerebral hemisphere after unilateral contraction of the hands in a study on motor performance, analyzing through EEG the connectivity between the left verbal-analytical temporal region and the motor planning region. The results of the study showed that hand contractions influence the extent of verbal-analytical engagement during motor planning, which in turn influences motor performance.

Goldstein et al. (2010) observed that unilateral hand contraction can affect cognitive performance by selectively activating either the right or the left hemisphere. Although numerous studies have shown that unilateral contraction of the hands or facial muscles can activate the contralateral cerebral hemisphere, having effects on emotional and motivational reactions (Peterson et al., 2008; Schiff et al., 1998), Goldstein et al. (2010) were among the first researchers to demonstrate the existence of cognitive effects as a result of hand contraction in a verbal creative problem solving task.

At the same time, Noufi and Zeev-Wolf (2021) showed that the contraction of the left hand and the implicit activation of the right hemisphere led to the improvement of novel metaphor comprehension. The logic of these studies starts from the fact that unilateral muscle contraction activates sensory and motor cortical areas in the contralateral cerebral hemisphere. By means of a mechanism of spreading activation to other cortical regions, a great diversity of emotional, motivational, attentional and cognitive processes can be influenced.

Harmon-Jones (2006) showed that contracting the left hand affects the functioning of the right frontal cortex, which is consistent with the assumption of spreading activation, which can explain why motor behaviors are able to enhance certain cognitive processes. Gable et al. (2013) tested the causal contributions of hemisphere activation to global-local processing. To manipulate the activation of the cerebral hemispheres, the participants engaged in contralateral hand contractions. The activity and attentional scope were measured through EEG. Right-hand contractions caused greater left-cortical activity than left-hand contractions. The results of the study showed that manipulating the left cerebral hemisphere improves the global attentional process, and manipulating the right cerebral hemisphere improves the local attentional process.

Propper et al. (2013) conducted a study on the effects of hand clenching on episodic recall using the HERA model. Their results not only confirmed the HERA model, but also the fact that simple hand contraction can be used as a means by which the functional specializations of the cerebral hemispheres can be investigated in humans.

Starting from the above, the present study aims to test the HERA model on a sample of Romanian students, using hand clenching to activate the cerebral hemispheres responsible for memory encoding and memory retrieval. Therefore, we will assume that participants who will use right hand clenching to activate the left cerebral hemisphere before encoding a list of words, and who will use left hand clenching to activate the right cerebral hemisphere before words retrieval, will retrieve more words than participants in other conditions.

2. METHODOLOGY

Participants

A number of 64 students participated in this study, all of them enrolled in the first and second study year at the University of Bucharest, Faculty of Psychology and Educational Sciences, Department of Special Education. The age of the participants ranged between 18 and 47 years, M = 20.66, SD = 4.84. Two of them were males (3%) and 62 females (97%), all of them right-handed, right laterality quotient ranging between 75 and 100, M = 99.92, SD = 4.38. Laterality was measured with the Edinburgh Handedness Inventory (Oldfield, 1971). Only right-handed participants were kept because they tend to exhibit greater functional lateralization effects than do left-handed people (Hellige, 1993). All participants also had normal or corrected-to-normal visual acuity. The initial number of participants was 74, but ten of them registered right laterality quotient lower than 75, so they were eliminated from the study. Participants were not rewarded in any way, and enrollment in the experiment was voluntary. They were randomly assigned to one of the five hand clenching conditions:

1. CLE - CRR (clenching left hand before encoding - clenching right hand before recalling),
2. CLE - CLR (clenching left hand before encoding - clenching left hand before recalling),
3. CRE - CLR (clenching right hand before encoding - clenching left hand before recalling),
4. CRE - CRR (clenching right hand before encoding - clenching right hand before recalling),
5. Control (no clenching).

The experimental design was inspired by the study of Propper et al. (2013).

Table 1. *Distribution and number of participants according to assigned condition*

Condition/ Participants	1. CLE-CRR	2. CLE-CLR	3. CRE-CLR	4. CRE-CRR	5. Control
Initial (n = 74)	16	15	16	15	12
Effective (n = 64)	14	12	14	13	11

Materials

Memory stimuli consisted of a list of 36 words chosen at random from the list of 72 words used by Tulving et al. (1982). The words were translated into Romanian.

Clenching stimuli. Participants in conditions 1, 2, 3, 4 were instructed by the experimenters to squeeze a 5 cm diameter rubber ball in their hand (left or right) as hard as they could for two sets of 45 seconds each, with a 15 second break between them. Participants in condition 5 (control) were instructed to hold the ball with both hands without squeezing it.

Procedure

The participants were tested in groups of eight, in a room within the faculty, isolated from the rest of the rooms, so that there were as few external stimuli as possible (noises, lights, etc.). Response forms for each participant were printed on paper, with the condition (1, 2, 3, 4, or 5) indicated on the form. Students randomly drew a form, which implicitly imposed the condition as well. Initially, 74 students drew forms: 16 for condition 1, 15 for condition 2, 16 for condition 3, 15 for condition 4, and 12 for condition 5. Each of the five groups was trained separately in a short session in that the experimenter explained the task to them and exemplified how they would have to clench the ball in one hand or the other. In a group of eight participants, students from all five conditions could be found. After the participants entered the room, the experimenter gave them the balls and made sure that each participant understood what task they had to perform.

Stage 1. The participants completed pre-encoding clenching, that is, they clenched the ball for 45 seconds in their right or left hand for conditions 1, 2, 3, 4 or held the ball with both hands without clenching it for condition 5. After the first 45 seconds of clenching followed 15 seconds of rest, then another 45 seconds of clenching with the same hand. The two sets of 45 seconds each and the 15-second break were timed and signaled to the participants by a timer sound. During the two sets of 45 seconds of clenching, participants were asked to look at a white projector screen, and focus on an "X" positioned in the center of the screen.

Stage 2. The participants were presented with the memory stimuli, the 36 words, through a set of slides made in PowerPoint, set to run one after the other at an interval of five seconds. The words were written in Courier New capitals, 28 point, but were projected onto the projector screen, so the actual size was much larger.

Stage 3. After the presentation of the 36 words, participants were asked to complete the Edinburgh Handedness Inventory (Oldfield, 1971) and another laterality questionnaire, the Waterloo Handedness Questionnaire (Coren, 1993), as a filler.

Stage 4. The participants completed pre-recall clenching, the procedure being identical to that of Stage 1, with or without hand change, depending on the assigned experimental condition.

Stage 5. The participants were asked to fill in as many as possible of the 36 words presented, on the response form, in paper and pencil. They were given 10 minutes for this task.

The total duration of the experiment from Stage 1 to Stage 5 was approximately 20 minutes.

3. RESULTS

To test the HERA model, we performed a one-way ANOVA for the five conditions, CLE - CRR (clenching left hand before encoding - clenching right hand before recalling), CLE - CLR (clenching left hand before encoding - clenching left hand before recalling), CRE - CLR (clenching right hand before encoding - clenching left hand before recalling), CRE - CRR (clenching right hand before encoding - clenching right hand before recalling), Control (no clenching), measuring the following variables: the number of correct words, the number of incorrect words (not found in the memory stimuli), the total number of written words (correct words plus incorrect words). The statistical analysis program IBM.SPSS 24 (IBM Corp, 2016) was used.

The highest number of correct words recalled was for participants in the CRE-CLR condition, M = 14.36, SD = 3.93, compared to participants in the CLE-CLR condition, M = 13.58, SD = 3.23, to participants in the CRE-CRR condition, M = 13.08, SD = 4.07, to participants in the CLE-CRR condition, M = 10.29, SD = 2.97, and to participants in the control group, M = 11.45, SD = 3.88.

The largest number of incorrect words recalled was in the participants in the CLE-CRR condition, M = 2.43, SD = 2.28, compared to the participants in the CRE-CLR condition, M = 1.86, SD = 1.23, to the participants in the CRE-CRR condition, M = 1.23, SD = 1.59, to participants in the control group, M = 1.00, SD = 1.18, and to participants in the CLE-CLR condition, M = .92, SD = 1.31.

The highest total number of total words (correct and incorrect) was in participants in the CRE-CLR condition, M = 16.21, SD = 4.30, compared to participants in the CLE-CLR condition, M = 14.50, SD = 3.03, to participants in the CRE-CRR condition, M = 14.31, SD = 4.01, to participants in the CLE-CRR condition, M = 12.71, SD = 2.20, and to participants in the control group, M = 12.45, SD = 3.11.

Table 2. *Descriptive statistics for the three variables in the five conditions*

						95% CI	
		N	M	SD	SE	Lower	Upper
Correct	CLE-CRR	14	10.29	2.97	.79	8.57	12.00
	CLE-CLR	12	13.58	3.23	.93	11.53	15.64
	CRE-CLR	14	14.36	3.93	1.05	12.09	16.63
	CRE-CRR	13	13.08	4.07	1.13	10.62	15.54
	Control	11	11.45	3.88	1.17	8.85	14.06
	Total	64	12.56	3.84	.48	11.60	13.52
Incorrect	CLE-CRR	14	2.43	2.28	.61	1.11	3.74
	CLE-CLR	12	.92	1.31	.38	.08	1.75
	CRE-CLR	14	1.86	1.23	.33	1.15	2.57
	CRE-CRR	13	1.23	1.59	.44	.27	2.19
	Control	11	1.00	1.18	.36	.21	1.79
	Total	64	1.53	1.65	.21	1.12	1.94
Total	CLE-CRR	14	12.71	2.20	.59	11.44	13.98
	CLE-CLR	12	14.50	3.03	.88	12.57	16.43
	CRE-CLR	14	16.21	4.30	1.15	13.73	18.70
	CRE-CRR	13	14.31	4.01	1.11	11.89	16.73
	Control	11	12.45	3.11	.94	10.37	14.54
	Total	64	14.09	3.60	.45	13.20	14.99

The ANOVA tests for correct words was significant, $F(4, 59) = 2.78$, $p < .05$, with an effect size $\eta 2 = .16$; for incorrect words was insignificant, $F(4, 59) = 2.12$, $p > .05$, with an effect size $\eta 2 = .13$; for total number of words was significant, $F(4, 59) = 2.59$, $p < .05$, with an effect size $\eta 2 = .15$ (Table 3).

Table 3. *One-way ANOVA analysis for the three variables in the five conditions*

		Sum of Squares	df	Mean Square	F	Sig.
Correct	Between Groups	147.11	4	36.78	2.78	.04
	Within Groups	780.64	59	13.23		
	Total	927.75	63			
Incorrect	Between Groups	21.57	4	5.39	2.12	.09
	Within Groups	150.37	59	2.55		
	Total	171.94	63			
Total	Between Groups	121.73	4	30.43	2.59	.04
	Within Groups	693.71	59	11.76		
	Total	815.44	63			

For a more detailed analysis of the results, the Fisher LSD post hoc test for simple effects was performed.

Table 4. *Post-hoc Fisher LSD test for* ***correct words*** *– simple differences among the five conditions*

(I) Cond	(J) Cond	MD (I-J)	ES	Sig.	95% CI Lower	95% CI Upper
CLE-CRR	CLE-CLR	-3.30*	1.43	.03	-6.16	-.43
	CRE-CLR	-4.07*	1.38	.00	-6.82	-1.32

There are significant differences only between CLE-CRR and CLE-CLR, MD = -3.30, $p < .05$, CI95%(-6.16, -.43) and between CLE-CRR and CRE-CLR, MD = -4.07, $p < .05$, CI95%(-6.82, -1.32).

Figure 2. *Graphical representation for the means of correct words in the five conditions*

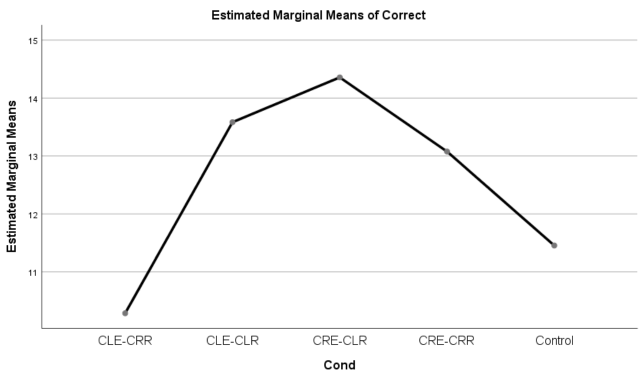


Table 5. *Post-hoc Fisher LSD test for* ***incorrect words*** *– simple differences among the five conditions*

(I) Cond	(J) Cond	MD (I-J)	ES	Sig.	95% CI Lower	95% CI Upper
CLE-CRR	CLE-CLR	1.51*	.63	.02	.26	2.77
	Control	1.43*	.64	.03	.14	2.72

Although the ANOVA analysis was not statistically significant, simple differences were observed between the five conditions, namely between CLE-CRR and CLE-CLR, MD = 1.51, $p < .05$, CI95%(.26, 2.77) and between CLE - CRR and Control, MD = 1.43, $p < .05$, CI95%(.14, 2.72).

Figure 3. *Graphical representation for the means of* ***incorrect words*** *in the five conditions*

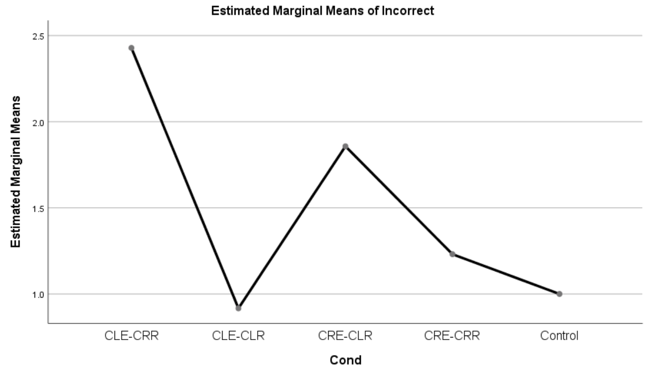
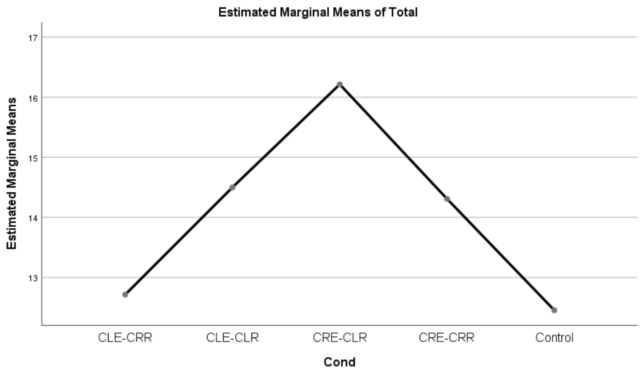


Table 6. *Post-hoc Fisher LSD test for* ***total number of words*** *– simple differences among the five conditions*

(I) Cond	(J) Cond	MD (I-J)	ES	Sig.	95% CI Lower	95% CI Upper
CLE-CRR	CRE-CLR	-3.50*	1.30	.01	-6.09	-.91

There are significant differences only between CLE-CRR and CRE-CLR, DM = -3.50, $p < .05$, CI95%(-6.09, -.91).

Figure 4. *Graphical representation for the means of* ***total number of words*** *in the five conditions*



4. DISCUSSION

The aim of the study was to test HERA model for episodic memory in a group of volunteer students. The results support the HERA model, in the sense that the number of correct words recalled by the participants was higher for those who activated their left cerebral hemisphere pre-encoding through right hand clenching and their right cerebral hemisphere pre-recalling through left hand clenching, compared to the participants in the other four conditions. Thus, participants in the CRE-CLR condition demonstrated better episodic memory. The results of Fisher LSD test for simple differences also support the HERA model for episodic memory, the highest differences being observed between the participants in the CRE-CLR condition and those in the CLE-CRR condition. At the same time, differences were observed between the participants in the CLE-CLR condition and those in the CLE-CRR condition, which underlines the importance of the activation of the right cerebral hemisphere for memory recall. Thus, participants who activated their right cerebral hemisphere pre-recall demonstrated better episodic memory.

Regarding the incorrect words, the largest number was observed in participants in the CLE-CRR condition. This result can be attributed to the fact that the activation of the right cerebral hemisphere pre-encoding does not support the memorization capacity to the same extent as the activation of the left cerebral hemisphere, and the activation of the left cerebral hemisphere pre-recalling does not support the retrieval of correct words. This fact is also reinforced by the differences between the participants in the CLE-CRR condition and those in the control group, the latter reporting a lower number of incorrect words in the situation where they did not activate either of the two cerebral hemispheres.

The total number of retrieved words, correct and incorrect, was higher in the participants in the CRE-CLR condition, with significant differences between them and those in the CLE-CRR condition. This result points to the retrieval of a larger number of words overall, thus a stronger activation of the left cerebral hemisphere.

Our study supports HERA model for episodic memory and is congruent with the results previously obtained by Tulving et al. (1994), Habib et al. (2003), Propper et al. (2005), Harmon-Jones (2006), Peterson et al. (2008), proving once again that: i) hand clenching activates contralateral cerebral hemisphere, and ii) left cerebral hemisphere is more involved in memory encoding, while right cerebral hemisphere is more involved in memory recalling.

Precautions and practical implications

Although the results of the present study support the HERA model and the different roles of the two cerebral hemispheres in the memory processes, it should be taken into account that the stimuli were a list of disparate words. The literature also presents studies that do not support HERA model for other types of stimuli, such as pictorial stimulus (artificial images generated by computer, silhouettes of common objects). Thus, Andreau and Torres Batan (2018) failed to support the HERA model for pictorial stimuli, but supported the model including pseudowords. It is therefore possible that the nature of the stimuli influences the memory processes, the authors considering that HERA enhances a specific pathway: when memorizing words, not only their semantic content is accessed, but they are recognized and rehearsed subvocally by converting graphemes into phonemes (Andreau & Torres Batan, 2018).

In an encoding task, Kelley et al. (1998) observed that: the activity of the right cerebral hemisphere was higher when the participants had to memorize words, the activity of the left cerebral hemisphere was higher when the participants had to memorize unfamiliar human faces, and both hemispheres were activated equally when memorizing the names of common objects. Wagner et al. (1998) observed an increased activation of the left hemisphere for verbal materials and increased activation of the right hemisphere for non-verbal materials, keeping encoding or retrieval tasks constant.

All these results sometimes question the HERA model, leading to different opinions. One such opinion is that the main determinant of hemispheric involvement in memory tasks is the nature of the material to be memorized, and the encoding and retrieval processes only modulate this determination (Epstein et al., 2002; Gazzaniga, 2000; Miller et al., 2002). Another opinion is that the hemispheric asymmetry between encoding and retrieval is only apparent and that it reflects the asymmetry between verbally oriented processing during encoding and less verbally oriented processing during retrieval (Lee et al., 2000a, b; Owen et al., 1996).

Despite these criticisms, the HERA model remains a benchmark that continues to be tested through the most sophisticated neuroimaging techniques, most of which confirm its credibility. From this perspective, we believe that the use of the model in educational practice can have important benefits in the learning process of students. If the activation of the contralateral cerebral hemispheres is possible through hand clenching, then programs for students can be developed, based on simple physical exercises, which lead to the activation of the left cerebral hemisphere, responsible for encoding, immediately before the teaching of some lessons (especially those with pronounced verbal support) and to the activation of the right cerebral hemisphere, responsible for retrieval, immediately before knowledge assessment tests.

Such a possible program can only be beneficial for students, while also contributing to the improvement of attention and preparation in advance of learning and testing. Moreover, students may be attracted to the idea that they can activate a certain cerebral hemisphere through their own actions, so they may pay more attention and become more interested in learning. Also, the implementation of a program based on physical exercises dedicated to the activation of the brain hemispheres specific to the learning context, is consistent with the new trends to introduce sports exercises in student classes with the aim of improving cognitive processing in general. Therefore, the HERA model can be the basis of such programs, starting from the premise that physical exercise is associated with higher cognitive performance, problem solving and memory (Bidzan-Bluma & Lipowska, 2018; Hillman et al., 2008; Tomporowski, 2003).

Limitations and further research directions

The present study presents a number of limitations. One of these is the small number of participants and the predominantly female gender. In addition, the participants were students, so generalizing the results should be done with caution. Also, students were not tested separately, but in groups of eight, which could have influenced the results to some extent, as students from all five conditions were included in one group. As a future research direction, we aim to use different stimuli (not only verbal), but also to attract groups of participants from among students with and without learning disabilities.

5. REFERENCES

Andreau, J. M., & Torres Batán, S. (2018). Exploring lateralization during memory through hemispheric pre-activation: Differences based on the stimulus type. *Laterality: Asymmetries of Body, Brain and Cognition*, 1–24. doi:10.1080/1357650x.2018.1531422

Baddeley, A., Conway, M. & Aggleton, J. (2001). Episodic memory. *Philosophical Transactions of the Royal Society B: Biological Sciences, 356*, 1341–1515.

Beckmann, J., Gröpel, P., & Ehrlenspiel, F. (2013). Preventing motor skill failure through hemisphere-specific priming: Cases from choking under pressure. *Journal of Experimental Psychology: General, 142*(3), 679–691. https://doi.org/10.1037/a0029852

Bidzan-Bluma I., Lipowska, M. (2018). Physical Activity and Cognitive Functioning of Children: A Systematic Review. *International Journal of Environmental Research and Public Health, 15*(4), 800. doi: 10.3390/ijerph15040800

Cabeza, R., Nyberg, L. (2000). Imaging cognition II: an empirical review of 275 PET and fMRI studies. *Journal of Cogitive. Neuroscience, 12*, 1–47. doi: 10.1162/08989290051137585

Coren, S. (1993). Measurement of handedness via self-report: the relationship between brief and extended inventories. *Perceptual and Motor Skills, 76*(3/1), 1035–1042. https://doi.org/10.2466/pms.1993.76.3.1035

Epstein, C. M., Sekino, M., Yamaguchi, K., Kamiya, S., Ueno, S. (2002). Asymmetries of prefrontal cortex in human episodic memory: effects of transcranial magnetic stimulation on learning abstract patterns. *Neuroscience Letters, 320*(1-2), 5-8. doi: 10.1016/s0304-3940(01)02573-3

Fletcher, P. C., Henson, R. N. (2001). Frontal lobes and human memory: insights from functional neuroimaging. *Brain, 124*, 849–881. doi: 10.1093/brain/124.5.849

Gable, P. A., Poole, B. D., & Cook, M. S. (2013). Asymmetrical hemisphere activation enhances global–local processing. *Brain and Cognition, 83*(3), 337–341. doi:10.1016/j.bandc.2013.09.012

Gazzaniga, M. S. (2000). Cerebral specialization and interhemispheric communication: does the corpus callosum enable the human condition? *Brain, 123*, 1293–1326. https://doi.org/10.1093/brain/123.7.1293

Goldstein, A., Revivo, K., Kreitler, M., & Metuki, N. (2010). Unilateral muscle contractions enhance creative thinking. *Psychonomic Bulletin & Review, 17*(6), 895–899. https://psycnet.apa.org/doi/10.3758/PBR.17.6.895

Habib, R., Nyberg, L., Tulving, E. (2003). Hemispheric asymmetries of memory: The HERA model revisited. *Trends in Cognitive Sciences, 7*(6), 241–245. doi: 10.1016/s1364-6613(03)00110-4.

Harmon-Jones, E. (2006). Unilateral right-hand contractions cause contralateral alpha power suppression and approach motivational affective experience.
Psychophysiology, 43(6), 598–603. doi: 10.1111/j.1469-8986.2006.00465.x

Hellige, J. B. (1993). *Hemispheric asymmetry: What's right and what's left.* Harvard University Press.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*(1), 58-65. https://doi.org/10.1038/nrn2298

Hirao, T., & Masaki, H. (2019). Effects of unilateral hand contraction on the persistence of hemispheric asymmetry of cortical activity. *Journal of Psychophysiology, 33*(2), 119–126. https://doi.org/10.1027/0269-8803/a000215

Hoskens, M. C. J., Bellomo, E., Uiga, L., Cooke, A., & Masters, R. S. W. (2020). The effect of unilateral hand contractions on psychophysiological activity during motor performance. *Psychology of Sport and Exercise*, 101668. doi:10.1016/j.psychsport.2020.101668

IBM Corp. (2016). *IBM SPSS Statistics for Windows, Version 24.0.* Armonk, NY: IBM Corp.

Kelley, W. M., Miezin, F. M., McDermott, K. B., Buckner, R. L., Raichle, M. E., Cohen, N. J., Ollinger, J. M., Akbudak, E., Conturo, T. E., Snyder, A. Z., Petersen, S. E. (1998). Hemispheric specialization in human dorsal frontal cortex and medial temporal lobe for verbal and nonverbal memory encoding. *Neuron, 20*(5), 927-936. doi: 10.1016/s0896-6273(00)80474-2

Lee, A. C., Robbins, T. W., Pickard, J. D., Owen, A. M. (2000a). Asymmetric frontal activation during episodic memory: the effects of stimulus type on encoding and retrieval. *Neuropsychologia, 38*(5), 677-692. doi: 10.1016/s0028-3932(99)00094-9

Lee, A. C., Robbins, T. W., Owen, A. M. (2000b). Episodic memory meets working memory in the frontal lobe: functional neuroimaging studies of encoding and retrieval. *Critical Reviews in Neurobiology, 14*(3-4), 165-197. PMID: 12645957.

Miller, M. B., Kingstone, A., Gazzaniga, M. S. (2002). Hemispheric encoding asymmetry is more apparent than real. *Journal of Cognitive Neuroscience, 14*(5), 702-708. doi: 10.1162/08989290260138609

Noufi, T. Zeev-Wolf, M. (2021). Activating the Right Hemisphere Through Left-Hand Muscle Contraction Improves Novel Metaphor Comprehension. *Frontiers in Psychology*. doi: 10.3389/fpsyg.2021.729814

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh
Handedness Inventory. *Neuropsychologia, 9*, 97–113. doi: 10.1016/0028- 3932(71)90067-4

Owen, A. M., Milner, B., Petrides, M., Evans, A. C. (1996). Memory for object features versus memory for object location: a positron-emission tomography study of encoding and retrieval processes. *Proceedings of the National Academy of Sciences of the United States of America, 93*(17), 9212-9217. doi: 10.1073/pnas.93.17.9212

Peterson, C. K., Shackman, A. J., & Harmon-Jones, E. (2008). The role of asymmetrical
frontal cortical activity in aggression. *Psychophysiology, 45*, 86–92. doi: 10.1111/j.1469-8986.2007.00597.x

Propper, R. E., Christman, S. D., Phaneuf, K. A. (2005). A mixed-handed advantage in episodic memory: a possible role of interhemispheric interaction. *Memory & Cognition, 33*, 75–77. doi: 10.3758/bf03195341

Propper, R. E., McGraw, S. E., Brunyé, T. T., Weiss, M. (2013). Getting a grip on memory: unilateral hand clenching alters episodic recall. *PLoS One, 8*(4), e62474. doi: 10.1371/journal.pone.0062474

Schiff, B. B., Guirguis, M., Kenwood, C., & Herman, C. P. (1998). Asymmetrical hemispheric activation and behavioral persistence: Effects of unilateral muscle contractions. *Neuropsychology, 12*(4), 526–532. doi: 10.1037//0894-4105.12.4.526

Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta Psychologica, 112*(3), 297-324. doi: 10.1016/s0001-6918(02)00134-8

Tulving, E,, Schacter, D. L., Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8*, 336–342. https://psycnet.apa.org/doi/10.1037/0278-7393.8.4.336

Tulving, E., Kapur, S., Craik, F. L., Moscovitch, M., Houle, S. (1994). Hemispheric encoding/retrieval asymmetry in episodic memory: Positron emission tomography findings. *Proceedings of the National Academy of Sciences of the United States of America, 91*, 2016–2020. doi: 10.1073/pnas.91.6.2016

Wagner, A. D., Poldrack, R. A., Eldridge, L. L., Desmond, J. E., Glover, G. H., Gabrieli, J. D. (1998). Material-specific lateralization of prefrontal activation during episodic encoding and retrieval. *Neuroreport, 9*(16), 3711-3717. doi: 10.1097/00001756- 199811160-00026

Ward, J. (2015). *The Student's Guide to Cognitive Neuroscience*. Psychology Press.

Wheeler, M. A., Stuss, D. T., Tulving, E. (1997). Toward a Theory of Episodic Memory: The Frontal Lobes and Autonoetic Consciousness. *Psychological Bulletin, 121*(3), 331-354. https://doi.org/10.1037/0033-2909.121.3.331