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THE EFFECTS OF PROPRIOCEPTION ON MEMORY: A STUDY OF PROPRIOCEPTIVE ERRORS AND RESULTS FROM THE REY-OSTERRIETH COMPLEX FIGURE IN A HEALTHY POPULATION

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SUMMARY

Background: The aim of the current study was to test whether or not proprioceptive errors (biases) are associated with visual memory performance, and to distinguish which movement types are more important in this relationship.

Material/ Methods: The study included 63 pupils with normal vision, including 49 pupils from a conventional school and 14 pupils from a school for slower children. We used the Proprioceptive Diagnosis (PD) test based on fine motor performance without self-body vision and the Rey-Osterrieth Complex Figure. Errors in different movement types were checked for Pearson correlation with ROCF test results. Linear regression analysis was performed to confirm whether or not the variables of ROCF depended linearly on specific proprioceptive indicators.

Results: The findings show that proprioception has effects on memory. Negative correlations of medium significance were found between Frontal Directional (FD), Sagittal Directional (SD) and Sagittal Line Length (SLL) movement types on the PD and Immediate memory on the ROCF, and between SLL movement type on the PD and Delayed Memory and Recognition on the ROCF. Significant correlations for directional deviations were found for the non-dominant hand, while for line length they were found for the dominant hand.

Conclusions: Proprioception has a significant effect on cognitive performance. A specific movement type – sagittal line length (SLL) deviation of the dominant hand – had a significant influence on immediate and delayed memory, as well as recognition. These findings confirm a significant relationship between proprioceptive information in behavior and cognition performance (in this case, visual memory).

Key words: cognitive processes, implicit memory, ROCF, motor control

INTRODUCTION

Following David Rosenbaum's remark that little attention is paid to motor control in psychology (Rosenbaum, 2005) and the results of proprioception for attention in a double task (Ingram, van Donkelaar, Vercher, Gauthier & Miall, 2000), we checked whether there was any research done on the relationship between proprioception and cognitive performance. Unfortunately, to date there is a scarcity of material published on this topic. However, the experiment done by Ingram and his colleagues showed a difference in results when the task was double (the motor task of matching and the cognitive task of counting backwards). The performance of a person with no proprioception was 60% worse than their results in the single motor task. When compared with the control group, however, performance was worse by only 10%. This experiment proved the importance of proprioception in cognitive performance, especially when attention needs to be distributed.

Gimse and colleagues (Gimse, Tjell, Bjorgen, Tyssedal & Bo, 1992) reported that decreased proprioception in post-traumatic whiplash resulted in emotional and cognitive disturbances.

Other researchers (Müler, von Schweder, Frank, Degler, Münt & Johannes, 2002) found that after muscular vibration therapy was applied to improve proprioception in patients with traumatic brain injury, their cognitive processes also improved in the reaction-choice task after therapy. In another study (Martin, Thompson, Blizzard, Wood, Garry & Srikanth, 2009) on the association of visuospatial ability and memory with the risk of falls in the elderly, it was found that executive functions, attention, and memory were independently and significantly associated with the risk of falls. Vieira, Quercia, Michel, Pozzo and Bonnetblanc (2009) showed that cognitive demands impair postural control, motor coordination and balance in children with dyslexia.

With these studies in mind, we set our goal for the current study to test whether or not proprioceptive errors (biases) and visual memory are negatively related, and to distinguish which movement types are more important in this relationship.

MATERIAL AND METHODS

Participants

The study included 63 pupils with normal vision (48% male, average age 14±1.2, range 12-17), of whom 49 pupils were from a conventional school and 14 pupils were from a school for slower children. Participants who had changed their hand dominance due to intentional educational enforcement at school were excluded from the study on account of this change. The main environmental issues that could influence the test results were taken into account:

- a silent laboratory with a comfortable ambient temperature was used for all tests;

- the pre-test instruction was not to consume any substances (coffee, drugs, etc.) that might affect fine motor activity;
- the subjects were helped to find a posture with the least tension for the upper limb movements.

All subjects participated voluntarily; they were previously informed of the aim of the research and their consent was duly given.

Instruments

For the Rey – Osterrieth Complex Figure (ROCF; Shin, Park, Park, Seol & Kwon, 2006), paper and pencils for drawing were provided.

To carry out the proprioceptive diagnosis (PD) test the following materials were provided:

- a touch screen (LGE with resolution 1280x1024 and optimal frequency 60 Hz) with a sensory stylus for hand drawings;
- a laptop computer (Pentium IV);
- specifically designed test software for the recoding and analysis of data;
- a piece of cardboard (or opaque screen) for the non-vision part of test, conceal the active arm and movement feedback;
- a stool that could be adjusted to the participant's height;
- a table;
- written and oral instructions for the correct task procedure and performance (Tous-Ral, Muiños, Tous & Tous Rovirosa, 2012; Tous-Ral, Muiños, Liutsko & Forero, 2012).

Procedure

The memory test was carried out using the ROCF, which involves copying the complex figure first (Copy), and then replicating it from memory after a short delay (to measure Immediate Recall), and then again from memory after 20-30 minutes (Delayed Recall). Finally, three sheets with eight figures on each were presented to the participants to check if they were present in the original figure or not (supplement, Recognition).

For proprioceptive control, the precision of fine motor performance (hand drawings over model lines) was measured by the PD (Tous, 2008) in the following directions (as shown in Fig. 1):

1) transversal movements from interior to exterior direction (horizontal lines in the horizontal position on the screen);
2) sagittal movements from inner to outer direction (vertical lines in the horizontal position on the screen);
3) frontal movements from lower to upper direction (vertical lines in the vertical position on the screen).

In order to obtain reliable data, the correct posture is required, and the stool and table heights have to be adjusted individually, allowing free elbow and arm movements. The following points should be checked before and during task performance for both parts of the test (with and without vision):

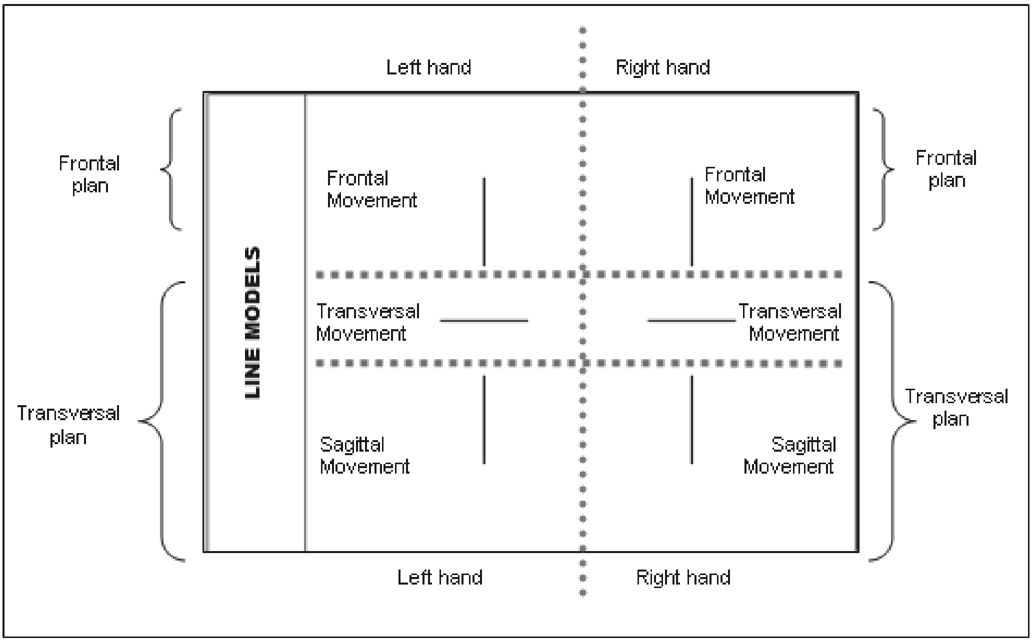

Fig. 1. Representation of the DP-TC test performance, tracing over the line model: 6 lines measuring hand movements in three directions (transversal, sagittal and frontal) for both hands (right and left)

a) body in upright position looking straight ahead (without leaning to the left or right during the graphic performance of the movements) with feet together on the floor,
b) seated comfortably without having to bend the back or extend the arms in an unnatural way;
c) the hand not being used in the task resting on the leg ipsilateral to it;
d) the hand and arm used for the task should have no tactile contact with anything (other than the stylus with which the drawing is performed), the wrist must be kept rigid, and the stylus should be held in the middle by the thumb, ring and index fingers, as when painting.

Data analysis

The data were analysed using SPSS software (version 16) to provide the descriptive statistics (Table 1), Pearson correlations for the PD and ROCF variables (Table 2), and a linear analysis of regression (Table 3).

RESULTS

In order to see if there is any relationship between proprioception (measured with the help of the PD for the upper limbs) and three parameters of memory (Immediate Recall, Delayed Recall and Recognition, obtained with the help of the ROCF), the Pearson correlations were found.

As seen in Table 2, all values from the PD were found to be significant for the non-dominant hand, reflecting the prevalence of the right hemisphere for better visual memory from proprioception information. Three significant correlations of medium strength were found for proprioceptive movements for Immediate Recall, while for Delayed and Recognition there was only one type, demonstrating that proprioception is reflected in the immediate memory process; however, immediate and delayed memory were closely linked, since there was a high correlation between the test results (r=.95) (see Table 2). The only movement type that

Table 1. Descriptive statistics of variables

				M	SE
Immediate memory				22.41	6.28
Delayed memory				22.13	6.26
Recognition				20.39	2.81
Proprioceptive variables (deviation types)	Movement type	Deviation type	Hand	M	SE
	Frontal	D	nd	-9.7	14.43
			d	-8.69	14.30
		F	nd	12.20	11.05
			d	13.29	10.50
		LL	nd	43.39	13.25
			d	41.76	10.19
	Transverse	D	nd	-2.64	15.48
			d	0.64	11.88
		F	nd	-2.64	15.48
			d	-3.34	10.73
		LL	nd	36.12	13.75
			d	33.00	8.67
	Sagittal	D	nd	9.48	12.66
			d	11.27	11.09
		F	nd	-2.30	11.72
			d	-3.45	12.67
		LL	nd	38.03	10.67
			d	35.26	7.85

Note: Legend for deviation type: D – frontal directional, F – frontal formal, LL – line length (the length of the model is 40 mm); Hand: d – dominant, nd – non-dominant.

showed significant relaion with all types of ROCF results (Immediate Recall, Delayed Recall, and Recognition) was SLL, line length biases in the sagittal task of the dominant hand, which for this reason could be chosen as a “marker” for the proprioceptive memory test.

For Immediate memory, a part of SLL, two more movement types for the non-dominant hand were found to have significant Pearson correlations to the Rey Complex Figure test results: FD and SD, which are directional deviations in the frontal and sagittal tasks. Finally, one extra analysis was done to measure the importance of memory in the children’s performance, and all three variables (Immediate Recall, Delayed Recall, and Recognition) had significant medium correlations with the pupils’ scores, with the highest score for Delayed Recall (see Table 2).

After regression analysis was performed (see Table 3 for results), in the multiple linear model IM = FD(nd) + SD(nd) + SLL(d), the variables SD(nd) and SLL(d) were significant predictors (R^2=.22 , $F(3,59)$=5.37, p=.002) of Immediate Recall, while FD(nd) was not confirmed (Table 3a). In both regressions – for Delayed Memory (DM) and Recognition (R) – the variable of line length error in the

Table 2. Correlations between ROCF test variables and PD test errors

		Immediate memory		Delayed memory		Recognition	
Immediate memory		1					
Delayed memory		.95**		1			
Recognition		.56**		.50**		1	
Marks		.38**		.40**		.31**	
Movement type	Deviation type	Non-dominant hand	Dominant hand	Non-dominant hand	Dominant hand	Non-dominant hand	Dominant hand
Frontal	D	-.27*	-.09	-.19	-.07	-.23	-.09
	F	-.12	-.12	-.12	-.07	.15	-.07
	LL	.05	-.18	.06	-.14	.03	-.17
Transverse	D	.10	-.11	.08	-.11	.16	.05
	F	-.02	-.04	-.01	-.07	.10	.08
	LL	-.10	.04	-.09	.00	-.19	-.11
Sagittal	D	-.32*	-.11	-.22	-.06	-.11	-.14
	F	.02	-.02	.01	-.04	.13	-.01
	LL	.02	-.32**	.04	-.34**	-.01	-.35**

Note: Legend for deviation type: D – frontal directional, F – frontal formal, LL – line length.

Table 3. Summary statistics, correlations and results from regression analysis

Multiple linear regression models for Immediate memory (IM):

variable	M	SE	correlation with IM, r	B	β
IM	22.46	6.31			
FD(nd)	-9.70	14.43	-.27*	-.07	-0.17
SD(nd)	9.48	12.66	-.32**	-0.13*	0.06*
SLL(d)	35.26	7.86	-0.32**	-0.22*	0.09*

Simple linear regression model for Delayed memory (DM):

variable	M	SE	correlation with DM, r	B	β
DM	22.21	6.28			
SLL(d)	35.26	7.86	-.34**	-0.27**	-0.34**

Simple linear regression model for Recognition:

variable	M	SE	correlation with R, r	B	β
R	20.44	2.80			
SLL(d)	35.26	7.86	-0.35**	-0.12**	-0.35**

Note: * p<.05, ** p<.01, *** <.001

sagittal direction for the dominant hand, SLL(nd), was a significant predictor explaining a significant proportion of the variance in ROCF scores, for DM (R^2=.12, F(1,61)=8.06, p=.006, see Table 3b) and for R (R^2=.12 , F(1,61)=8.34, p=.005, see Table 3c). Thus the regression analysis revealed that SLL(nd) is a significant predictor for all variables of the ROCF test (Immediate Recall, Delayed Recall, and Recognition); however, for IM there was an additional predictor: directional error in sagittal movement of the non-dominant hand, SD(nd).

CONCLUSIONS

Proprioception appears to have a significant effect for on cognitive performance. However, a specific movement type was found to have a significant association with both immediate and delayed recall, as well as recognition: sagittal line length (SLL) deviation in the dominant hand. These findings confirm the existence of a significant relationship between proprioceptive information in behaviour and cognition performance (visual memory in this case).

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REFERENCES

Ingram, H.A., van Donkelaar, C.J., Vercher, J-L., Gauthier, G.M. & Miall, R.C. (2000). The role of proprioception and attention in a visuomotor adaptation task. *Experimental Brain Research, 132*, 114-126.

Gimse, R., Tjell, C., Bjorgen, I., Tyssedal, J. & Bo, K. (1992). Decreased proprioception and effect on brain function. *Spine, 17(2)*, 127-131.

Martin, K., Thomson, R., Blizzard, L., Wood, A., Garry, M. & Srikanth, V. (2009). Visuospatial ability and memory are associated with falls risk in older people. *Dementia & Geriatric Cognitive Disorders, 27*, 451-457.

Müler, S., von Schweder, A., Frank, B., Degler, R., Münt, T. & Johannes, S. (2002). The effects of proprioceptive stimulation on cognitive processes in patients after traumatic brain injury. *Archives of Physical Medicine & Rehabilitation*, *83*,115-121.

Rosenbaum, D. A. (2005) The Cinderella of psychology: the neglect of motor control in the science of mental life and behavior. *American Psychologist, 60(4)*, 308-317.

Shin, M.S., Park, S.Y., Park, S.R., Seol, S.H. & Kwon, J.S. (2006). Clinical and empirical applications of the Rey-Osterrieth Complex Figure Test. *Nature Protocols, 1(2)*, 892–899. doi:10.1038/nprot.2006.115.

Tous, J.M. (2008), Diagnostico Propioceptivo del Temperamento y el Carácter DP-TC (software). Barcelona: Lab. Mira y López.

Tous Ral, J.M., Muiños, R., Tous, O. & Tous Rovirosa, J.M. (2012). Diagnóstico propioceptivo del temperamento y el carácter. Barcelona: Universidad de Barcelona.

Tous-Ral, J.M., Muiños, R., Liutsko, L. & Forero, C.G. (2012). Effects of sensory information, movement direction and hand use on fine motor precision. *Perceptual & Motor Skills, 115(1)*, 261-272. doi: 10.2466/25.22.24.

Viera, S., Quercia, P., Michel, C., Pozzo T. & Bonnetblanc, F. (2009). Cognitive demands impair postural control in developmental dislexia: A negative effect that can be compensated. *Neuroscience Letters, 462(2)*, 125-129.

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APPENDIX A

List of abbreviations

d – dominant hand

nd – non-dominant hand

Types of precision errors:

D – directional bias (deviation, measured parallel to the model)

F – formal bias (deviation , measured perpendicularly to the model)

LL – changes in line length (compared to the model of 40 mm length)

FD(nd) – Directional bias in Frontal movement type and non-dominant hand

SD(nd) - Directional bias in Sagittal movement type and non-dominant hand

SLL(d) – Line Length change error in Sagittal movement type and dominant hand