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PRIMING EFFECTS IN INDIVIDUALS WITH CORPUS CALLOSUM PATHOLOGY

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SUMMARY

Background: One of the methods that allow us to investigate the lateral organization of involuntary memory is priming. Originally this method was developed as a way to examine visual perception and visuomotor coordination in a cognitive paradigm. Eventually, however, it became clear that the capabilities of priming are much broader. Among other things it provides a unique possibility to examine involuntary memory in subjects with corpus callosum pathology (CCP), since it allows stimuli to be presented in different visual hemifields. The aim of our study was to identify and analyze the contribution of interhemispheric interaction in the work of involuntary memory.

Material/ Methods: In our study we examined 52 normal subjects and 16 subjects with CCP, using the method of priming.

Results: We discovered that in normal subjects there was a significant correlation between reaction time (RT) and priming. In the case of a relevant prime, RT decreased; in the case of an irrelevant prime, RT increased. We also discovered that in conditions with no priming, the right hemisphere reacts faster than the left. In subjects with CCP we observed priming system impairment: RT increased when the experimental conditions required interhemispheric interaction.

Conclusions: Our experiment demonstrated that the corpus callosum has a major influence on the process of selectivity in involuntary memory and learning, and in normal subjects distributes the energy between the brain hemispheres, suppressing the subdominant hemisphere in the present activity, thus forcing interhemispherical asymmetry.

Key words: bilateral asymmetry, interhemispheric interaction, involuntary memory

INTRODUCTION

Split Brain Syndrome, as described in neuropsychology, includes impairments of perceptual and motor activity, more specifically impairments in the coordination of motor responses in bimanual task,s as well as in perception, speech and spatial perception (Gazzaniga, 2004; Moskovitchute, Simmernitskaya, Smirnov & Filatov, 1982; Khomskaya, 2007). Since there are distinct lateral differences in memory impairments, we can assume that different aspects of memory activity are variously lateralized. The fact that memory is a complex holistic integrative activity means that our brain needs a mechanism of interaction of left-and right-brain functions. We can logically assume, then, that the corpus callosum plays a role in the integration of memory processes, and that if CCP occurs, the whole memory system suffers, since the corpus callosum connects all cortical sections of the left and right hemispheres.

There is little data, however, regarding the specific nature of memory impairments in cases of corpus callosum pathology (CCP; Simmernitskaya, 1989; Guise et al., 1999; Mayers & Sperry, 1985; Zaidel & Sperry, 1974). On the one hand, this lack of evidence can be explained by the instability of the symptoms (Clark & Geffen, 1989; Gazzaniga, 2000). On the other hand, studies of CCP are traditionally focused on the measurement of the voluntary aspect of mental activity. In these studies, several authors have noted the similarity of symptoms of CCP and right hemisphere damage (RHD; Buklina, 2004; Kovyazina & Balashova, 2009). We can assume, moreover, that specifically involuntary processes (lateralized in the right hemisphere) are the first to suffer in patients with the loss of interhemispheric connectivity based on CCP. Symptoms in this case are more stable because of the lack of compensation. Thus it is exactly the involuntary memory system that is the most vulnerable in case of CCP.

Involuntary memory is the individual's ability to store, retain, and recall information and experiences without conscious effort (Falikman & Koyfman, 2005). Involuntary memory (compared with voluntary) is an automatic process, and is characterized by a high rate of processing speed, a lack of flexibility, and a lack of conscious awareness (Gippenreiter & Romanov, 2000; Falikman & Koyfman, 2005). It mostly consists of perception and motor skills. Neuroimaging studies demonstrate that voluntary and involuntary memory involves fundamentally different structures, which function almost independently (Buckner et al., 1996).

The involuntary level of memory activity includes skills, which are the consequence of automatic, repeated, stereotyped and unconscious actions, as well as priming effects.

Learning in psychology is traditionally described as the process of acquiring changes of the individual's cognitive and behavioral patterns in accordance with previous experience. The learning ability of the brain (the ability to develop new skills) is connected with neuroplasticity (the ability of the human brain to change as a result of one's experiences). The most studied phenomenon here is the plasticity of the primary sensory and motor cortex (Grunwald, 2008). The corpus callosum, which is responsible for the integrative activity of the brain hemispheres and the interhemispheric transfer of information, supports the normal functioning of the motor sphere and perception systems, and hence influences sensorimotor learning. Therefore, symptoms of CCP occur primarily in the sensorimotor area (Korsakova, 2007).

Another subsystem of involuntary memory, besides sensorimotor learning, is the perceptual subsystem, which traditionally includes priming effects. The priming effect is a change in the velocity and accuracy of a reaction after the presentation of information, which is connected with the content or context of the task, but not directly correlated to its purpose and requirements. Priming effects can also be observed in the increased probability of spontaneous retrieval of this information in suitable conditions (Falikman & Koyfman, 2005). There are different types of priming (on several grounds):

- emotional and cognitive;
- conscious and unconscious;
- perceptual and semantic (perceptual coding is based on the resemblance of objects, and semantic coding includes semantic categorization of objects).

Studies of the interhemispheric transfer of involuntary memory traces in the situation of unconscious priming in normal subjects with intact brain commissures have revealed that reaction time (RT) does not change between the ipsi- or contralateral presentation of prime and target (Reynvoet, Ratinckx & Notebaert, 2008). RT decreases when prime and target are relevant and increases if they are not. Studies of emotional priming have discovered that emotionally intense words, presented subliminally, influence RT in positive and negative targets. The most rapid responses have been observed in the case of emotional congruity between primes and targets. However, subjects with a high level of anxiety significantly slow down after the presentation of subliminal, emotionally negative priming (Hermans, Spruyt, De Houwer & Eelen, 2003).

Similar studies have been conducted with subjects with ACC or childhood collosotomy (Forget, Lippe & Lassonde, 2009). These investigations demonstrate the lack of interhemispheric transfer of information pertaining to subliminal perception. Ipsilateral priming effects were no different from control subjects.

There is, then, impairment of the interhemispheric transfer of involuntary memory traces in CCP. It remains to be determined, however, traces cannot be transferred.

The purpose of our study was to identify and study the contribution of interhemispheric interaction in the work of involuntary memory.

MATERIAL AND METHODS

The experimental group consisted of 11 patients with CCP of various origin (full or partial agenesis of the corpus callosum, hypoplasia of the corpus callosum, dysgenesis of the corpus callosum, atrophic processes, tumors, or vascular lesions). The oldest experimental subject was 73 years old, the youngest was 9.

The control group consisted of 43 healthy, normal right-handed subjects. The oldest was 53 years old, the youngest was 17.

The experiment was conducted during standard clinical neuropsychological examinations. The subjects with CCP demonstrated a tendency to unilateral spatial neglect and other spatial errors. In the tactile sphere, we could observe single anomy errors. There were insignificant difficulties in performing a bimanual reciprocal task in praxis (mostly in the left hand) and difficulties in switching the pose of the fingers without visual control. There were also some unspecific impairments in voluntary memory in situations with interference.

In our experiment we presented the subjects with two photos in the left or right visual field. The subjects had a task of binary classification: if they saw a photo of the first person, they had to push the right button on the keyboard, while if they saw a photo of the second person, the left. Target presentation was preceded by short subliminal presentation (5 ms) of the same or different photo (relevant or irrelevant prime). There was also a series of control trials without any priming at all. In the center of the screen there was a fixation point.

Every trial went the same way. There was 5 ms of priming (or just a dark screen in trials without priming). After a 500 ms pause (dark screen) there was a 1500-ms presentation of the target, to which the subject reacted as instructed. The trial ended with a 1000-ms pause.

We composed the stimuli in pairs (prime – target), which differed in the following respects:

- presence or absence of priming;
- relevancy or irrelevance of the prime;
- the visual field of prime and target presentation:
- prime and target appear in the right visual field;
- prime and target appear in the left visual field
- prime appears in the right, and target in the left visual field;
- prime appears in the left, and target in the right visual field.

Thus there were 20 different pairs of stimuli, each of which was presented to the 20 times in random order. The experiment lasted 21.5 minutes.

We analyzed only correct responses. We got 400 RTs for each subject, divided into 10 groups of answers:

1. no priming, target on the left;
2. no priming, target on the right;
3. relevant prime on the left, target on the left;
4. relevant prime on the left, target on the right;
5. relevant prime on the right, target on the right;
6. relevant prime on the right, target on the left;
7. irrelevant prime on the left, target on the left;
8. irrelevant prime on the left, target on the right;
9. irrelevant prime on the right, target on the right;
10. irrelevant prime on the right, target on the left.

The results from each group were compared with each other using the non-parametric Mann-Whitney test.

RESULTS

The results from the control group were as follows:

1. In the absence of priming (conditions 1 and 2) the RT was significantly shorter in the case of a target in the left visual field (U = 645, p = 0.001).
2. In all cases of relevant prime (conditions 3-6), there was significantly shorter RT as compared to no priming and target on the same visual field (3: U = 532, p = 0.014; 4: U = 551.5, p = 0.001; 5: U = 612, p = 0.002; 6: U = 584, p = 0.02).
3. In all cases of irrelevant prime and target (conditions 7-10) there was significantly increased RT compared to no priming and target on the same visual field (7: U = 519, p = 0.002; 8: U = 481, p = 0.011; 9: U = 602, p = 0.001; 10: U = 575, p = 0.004).

Thus there was a significant correlation in control subjects between RT to the target and priming. In the case of a relevant prime, RT decreased. In the case of an irrelevant prime, RT increased. We also discovered that in conditions with no priming, the right hemisphere reacted faster than left.

The patients with CCP (the experimental group) demonstrated the following when performing the experimental tasks:

1. In trials without priming (conditions 1-2), the subjects with CCP demonstrated no significant differences between the trials with target presented in the left and right visual field, due to the increased RT of the left hemisphere(U = 113, p = 0.625). In both conditions 1 and 2 RT did not significantly differ from the normal RT (1: U = 72, p = 0.315; 2: U = 108, p = 0.571). Although there was a tendency in condition 2 (no priming, target on the right) to decreased RT compared with normal RT, this was caused by reduced hemispheric asymmetry in RT in cases without priming in the subjects with CCP. This fact can be explained by assuming that in the case of impairment of interhemispheric interactions, the right hemisphere ceases to suppress the left, and so the left hemisphere shows increased activity. Thus, normally the corpus callosum performs the function of distributing activity between the hemispheres, which is necessary in order for the dominant hemisphere to suppress the subdominant.
2. In the trials in which prime (whether relevant or irrelevant) and target were presented in the right visual field (conditions 5 and 9), we observed a significant decrease of RT in comparison with the condition 2 (target on the right, no priming; 5: U = 66.5, p = 0.035; 9: U = 85, p = 0.007). Thus the left hemisphere cannot distinguish primes properly, but it detects the formal presence of priming and categorizes any priming as correct. Because of the fact that the left hemisphere is dominant in conscious processes, it can tell (fixate) the presence of priming (i.e. determine that there is an image that flashes before the target), still, it cannot tell specifically which particular prime was presented, because the right hemisphere is dominant in the processing of unconscious

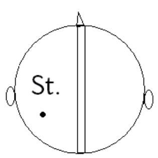
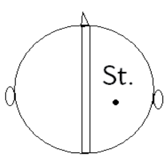
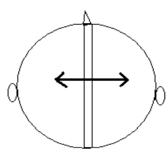
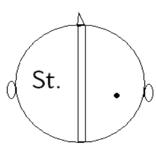
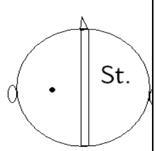
information. The left hemisphere, isolated from the right, is able to learn (acquire a skill) on the basis of the formal presence of priming: a relevant prime is assessed as proper, and an irrelevant prime is underestimated. We should also note that in condition 9 (irrelevant prime and target, both on the right) there is decreased RT compared with normal results (U = 124, p = 0.023). In condition 5 (relevant prime and target, both on the right) there were no significant differences from normal results (U = 154, p = 0.587). Thus the left hemisphere reacts properly to the presence of a relevant prime by decreasing RT (it begins to act normally). However, in the case of irrelevant priming, the left hemisphere reacts the same way: RT decreases to the level of relevant priming. In the control group, in all cases including irrelevant primes and targets, we observed increased RT compared with no-priming trials. In other words, in the case of irrelevant priming, much more time is needed for the comparison of prime and target and the inhibition of the wrong reaction. In the case of CCP this does not happen. Such responses from the left hemisphere in subjects with CCP can be called impulsive, and such answers can be observed in clinical neuropsychology in pathology of the basal prefrontal lobes; they are also considered symptomatic of impairment in the neurodynamics of mental activity, including also memory.

3. When primes (whether relevant or not) and targets are presented in the left visual field (conditions 3 and 7) there were no significant differences between condition 1 (no priming, target in the left) (3: U = 65, p = 0.427; 7: U = 102, p = 0.675). Thus the RT of the right hemisphere, isolated from the left, was not different from RT with no priming in subjects with CCP and in normal controls. The right hemisphere ignores the presence of priming. The RT does not show any learning. But such indifference to the very presence of priming itself can be connected with the fact that in normal interhemispheric interaction the left hemisphere is dominant for the fixation of memory traces (which is confirmed by the left hemisphere RT, which fixated the presence of priming, but did not process its content). The right hemisphere, in cases of CCP, cannot fixate the memory traces on its own, which is why it acts exactly as thought there were no traces at all. In other words, we can speak of a tendency to left unilateral neglect, on the involuntary level of memory activity, caused by the impairment of interhemispheric interactions. Another explanation may be that even if the isolated right hemisphere can fixate involuntary memory traces, they are quite incapable of influencing current activity (reacting to the target). Either way, then we observe impairment of the work of the involuntary memory system.
4. In all trials, when prime and target, whether relevant or not, were presented in contralateral visual fields (conditions 4, 6, 8, 10), we observed increased RT compared with conditions 1 and 2 (no priming) (4: U = 56, p = 0.024; 6: U = 107, p = 0.007; 8: U = 40, p = 0.016; 10: U = 23, p = 0.01). In all these conditions the influence of interhemispherical interactions on reaction increases, and we can analyze the variability of this impact compared with normal subjects. The difference depends not only on the slowdown of RT

(compared with normal subjects and conditions 1 and 2), but also with the fact that both hemispheres fail to react properly to any priming. In fact, the hemispheres do not “see” relevant priming. On the one hand, the brain notices the differences (and this matches conditions 5 and 9); on the other hand, these differences do not automate and do not lead to learning (which matches conditions 3 and 7). Irrelevant primes are estimated correctly and relevant primes are overestimated. This situation can be seen as compensatory, with the participation of both hemispheres in the process of reaction. The right hemisphere cannot ignore the presence of priming, as it appears in the case of the hemispheres functioning in isolation, because the left hemisphere fixates the presence. The left hemisphere cannot ignore the content processing of the right hemisphere, which interferes with building formal skills (such as reacting only to the presence of priming). But in subjects with CCP, the transfer of information about the presence and content of the stimuli occurs through compensatory paths (subcortical structures and anterior commissure), which significantly slows down the work of involuntary memory, and in the case of rapid activity does not allow the skill to form. In every case, the prime processes as irrelevant, which leads to decreasing the probability of error. Thus, compensation goes in the direction of rejecting the automatic, rapid, inflexibile unconscious processes in favor of more energy-intensive ways of reaction.

Thus our experiment demonstrated that the corpus callosum performs the function of distributing energy between the brain hemispheres, and suppresses the subdominant hemisphere in the present activity, forcing interhemispherical asymmetry, by suppressing the identical process in the subdominant hemisphere. The corpus callosum also significantly influences the process of selectivity in involuntary memory and learning.

Table. 1. The main results of the study

Variants of presentation («St.» – stimulus; «·» – prime)	 8, 4	 6, 10		
			 7, 11	 5, 9
Control group	In the case of a relevant prime, RT decreased. In the case of an irrelevant prime, RT increased.			
Patients with CCP (experimental group)	Any prime perceived as relevant.	Not seen any prime.	Any prime perceived as irrelevant.	Any prime perceived as irrelevant.

To further clarify these results it would be useful to match our experimental data with data obtained from groups of subjects with unilateral local brain lesions, i.e. patients with pathology of the right and left hemispheres.

DISCUSSION

The group of patients with pathology of the CC and right and left hemispheres of brain have the same response to non-verbal visual stimuli. In this case we can speak about leveling the differences between the hemispheres, by increasing the time of reaction of the left hemisphere of the brain (at the level of critical importance). This may be the evidence of the fact that the left hemisphere is no longer to endure the inhibitory influence from the right hemisphere (see also Nikolaenko & Pachalska 2008; Pachalska et al 2008). In all conditions which require the transfer of information between the hemispheres of the brain, we can notice a significant increase in time of reaction in the experimental group, regardless of whether stimuli are congruent or not. In healthy subjects, this dependence is clearly discernible. This may indicate the decrease in efficiency and hemispheric interaction. Normally, the CC realizes a redistribution of activity between the hemispheres of the brain and has an inhibitory effect on the activity in the subdominant hemisphere, increasing interhemispheric differences and suppressing an identical process in the next hemisphere. The experiment showed an abnormality of the priming effect in patients with dysfunction of hemispheric interaction.

CONCLUSIONS

Our experiment demonstrated that the corpus callosum has a major impact on the process of selectivity in involuntary memory and learning, and in normal subjects distributes the energy between the brain hemispheres and suppresses the subdominant in the present activity, forcing interhemispherical asymmetry.

REFERENCES

Buckner, R. L., Raichle, M. E., Miezin, F. M. & Petersen S. E. (1996). Functional anatomic studies of memory retrieval for auditory words and visual pictures. *Journal of Neuroscience, 16(19)*, 19-35.

Buklina, S. B. (2004). Mozolistoye telo, mezhpolusharnoye vzaimodeistviye y funkcii pravogo polushariya. *Zhurnal nevrologii y psychiatrii*, *5,* 8-14.

Khomskaya, E. D. (2007). *Neiropsychologiya*. St. Petersburg: Piter.

Clark, C. R. & Geffen, G. M. (1989). Corpus callosum surgery and recent memory. *Brain, 112(1)*, 165-175.

Falikman, M. V. & Koyfman, A. Y. (2005). Vidy praiminga v issledovaniyah vospriyatiya y perceptivnogo vnimaniya. *Vestnik Moskovskogo Universiteta*, Series 14: *Psykhologiya*, Vol. 3, 86-97; Vol. 4, 81-89.

Forget, J., Lippe, S. & Lassonde, M. (2009). Perceptual priming does not transfer interhemispherically in acallosal brain. *Experimental Brain Research, 192(3)*,443-454

Gazzaniga, M. S. (2000). Cerebral specialization and interhemispheric communication: does the corpus callosum enable the human condition? *Brain, 123*, 93-126.

Gazzaniga, M. (2004). Rassheplenniy chelovecheskiy mozg. In: E. D. Khomskaya (ed.), *Khrestomatiya po neiropsykhologii* (pp. 212-218). Moscow: Institut obshegumanitarnyh issledovaniy, Moskovskiy psykhologo-socialniy institut.

Grunwald, M., ed. (2008). *Human haptic perception: basics and applications*. Basel, Switzerland: Birkhäuser.

Guise, E., Pesce, M., Foschi, N., Quattrini, A., Papo, I. & Lassonde, M. (1999). Callosal and cortical contribution to procedural learning. *Brain, 122*, 49-62.

Hermans, D., Spruyt, A., De Houwer, J. & Eelen, P. (2003). Affective priming with subliminally presented pictures. *Canadian Journal of Experimental Psychology, 57(2)*, 97-114.

Korsakova, N. K. & Moskovitchute, L. I. (2007). *Klinicheskaya neiropsikhologiya*. Moscow: Izdatelskiy Centr “Akademiya”.

Kovyazina, M. S. & Balashova, E. Y. (2009). Osobennosti vysshih psyhicheskih funkciy pri patologii mozolistogo tela. *Vestnik Tomskogo Gosudarstvennogo Universiteta*, *113*, 193-200.

Mayers, J. J. & Sperry, R. W. (1985). Interhemispheric communication after section of the forebrain commissures. *Cortex, 21*, 249-260.

Moskovitchute, L. I., Simmernitskaya, E. G., Smirnov, N. A. & Filatov, Y. F. (1982). O roli mozolistogo tela v organizacii vysshih psychicheskih funkciy. In: E. D. Khomskaya, L. S. Tsvetkova, B. V. Zeigarnik (eds.), *A. R. Luria y sovremennaya psychologiya: Sbornik statey pamyati A. R. Lurii* (pp 143-150). Moscow: Izdatelstvo Moskovskogo Universiteta.

Nikolaenko N.N., Pąchalska M., 2008. Neuropsychological aspects of artistic creativity. Acta Neuropsychologica, 6(2):177-206

Gippenreiter, Y. B. & Romanov, V. Y., eds. (2000). *Psykhologiya pamyati*. Moscow: CheRo.

Pachalska, M., Grochmal-Bach, B., Wilk, M., Bulinski, L. (2008) *Rehabilitation of an artist after right-hemisphere stroke*. Med. Sci. Monit., 14 (10), 110–124.

Reynvoet, B., Ratinckx, E. & Notebaert, K. (2008). Intra- and interhemispheric number priming: evidence for rapid integration of magnitude information between hemispheres. Cortex, 44(6), 728-36.

Simmernitskaya, E. G. (1989). Neiropsykhologicheskaya diagnostika narusheniy pamyati pri porazheniyah mozolistogo tela. In: E. D. Khomskaya (ed.), *Novye metody neiropsykhologicheskogo issledovaniya* (pp. 159-175). Moscow: Izdatelstvo Instituta Psychologii AN SSSR.

Zaidel, D. W. & Sperry, R. W. (1974). Memory impairment after commissurotomy in man. *Brain, 97*, 263-272.

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