Effect of Semantic Priming for Wide Attention Focus on Visuomotor Decision-making Task in Young and Older Non-professional Drivers

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Abstract: *The study was aimed at estimating the semantic priming effect for wide attention focus on subjects response time (RT) in a decision-making visuomotor hand movement task (VMHT) performed in traffic scenarios for non-professional driver's license tests. The priming was based on modified scrambled sentence task. Traffic scenarios were displayed either on whole screen or within the central 25% of the screen. VMHT was presented: 1) immediately after priming; 2) after primed in the same way adaptation of reactive visual saccade; 3) without priming and saccade adaptation. Thirty young and thirty older subjects took part in the study as they were divided equally into three groups with respect to the three conditions: 1) YP and OP (a group where the traffic test is performed before the sacccade adaptation); 2) YS and OS (after the saccade adaptation); 3) YC and OC (control group). The outcomes established that RTs of both YP and OP groups are higher while RTs of YS and OS groups are lower in comparison with the control groups. RTs of all older groups were significantly longer than those of the younger groups. Longer RTs were found with respect to large pictures than to small pictures. These results suggest that semantic priming has a rather negative effect on decision-making VMHT performance because priming with scrambled sentences also involves a decision-making process. Therefore, they both need similar cognitive resources of which probably VMHT is deprived by the preceding priming and as consequence its perceptual realization is delayed. The study suggests that priming and visuomotor performance are related and the effect of the former on the latter depends on which cognitive resources they need.*

Keywords: *Spatial selective attention, Reaction time, Saccade adaptation.*

Introduction

The general definition of visuomotor response is related to the connection between vision and movement. In most cases of daily life, visuomotor responses represent hand movements responding to moving visual objects or standing balance as a complex process requiring precise interplay between vision, perception and muscles that were examined by different electrophysiological methods for posture and movement analysis [18, 27, 32]. Visuomotor responses are also the eye movements themselves as they present ocular muscles' movements following a moving visual scene.

Visuomotor integration depends upon the efficient control of eye movements, adequate vision, and the ability to plan the motor act and carry out the required motor task. Thus, the contribution of attention to the visuomotor responses is of major importance for their exact performance. According to literature data adaptation of both the visual saccades and the visuomotor hand behavior are attention related, i.e., the adaptive processes are attention demanding [4, 12]. Thus the increase of attention contribution to visuomotor tasks' performances could improve them.

One of the approaches for such an improvement known from the literature is the unconscious[1] priming and in particular, semantic priming. Semantic processing of sequences of words requires the cognitive system to keep several word meanings simultaneously activated inworking memory with a limited capacity [20]. As the contextual response in humans is based on semantic relationships between sentence elements stored in memory, semantic priming is one of the often used experimental methods [17, 19, 22]. It has been considered as an unconscious induction of cognitive attention. Recent brain imaging evidence suggests that unconscious stimuli can alter behavior, via unconscious processes [11, 25]. Neural models of behavior elicited by visual stimuli implicate the prefrontal and cingulate cortices in the regulation of subcortical brain regions linked to unconscious stimulus perception [26]. Therefore, one might assume that conscious cognitive processes, such as decision-making, that are associated with prefrontal cortex networks, are influenced by non-conscious experiences.

Although, different types of semantic priming were applied in experimental conditions, the most used semantic priming is the scrambled sentence task which was introduced by Bargh et al. [2] and was applied later to different behavioral tasks [4, 10, 21, 33]. This test manipulates a person's mental state under the pretext of a language proficiency test. As participants remain unaware of the manipulation, they cannot set up cognitive defenses that otherwise would attenuate the magnitude of induced effects. Two recent studies using priming with scrambled sentences for different types of attention, namely positive/negative age stereotypes [7] and wide/narrow focus of spatial attention [9], showed that priming with positive age stereotype and wide attention focus improved the adaptation of visual saccades. Visuomotor adaptation is considered to be a largely unconscious process as it is predominantly determined by sensorimotor recalibration, although a strategic component contributes to its benefit [1, 13]. In the cited above studies [7, 9], it was shown that the semantic priming increased the strategic component contribution while sensorimotor recalibration was not affected. A finding like that cited above [16] also confirmed the suggestion that conscious cognitive processes are influenced by non-conscious experiences [24].

However, as saccadic adaptation is a complex task consisting of mostly unconscious processes with contribution of a strategic component, it is difficult to explain the mechanism of unconscious semantic priming on its cognitive element. A recent study which used semantic priming with presented and then masked words denoting wide/narrow attention focus, found a discrimination effect on reaction times (RTs) of directed hand movements to objects in respective large/small pictures in a decision making task [16]. As we used the same words for priming in our study on saccade adaptation but presented them in a scrambled sentences task, we decided to apply this test to asses hand movement RTs in the similar decision making task.

Therefore, the aim of the present study was to examine whether the beneficial semantic priming effect on the predominantly cognitive visuomotor task would have a similar effect on an adaptation task relying mostly on unconscious processes. Possible evidence supporting a similar mechanism of priming effect on both visuomotor tasks could be its sharing, i.e., when they followed one after another the priming effect on the second task performance to be

[1]The processes in the mind which occur automatically.

reduced. Furthermore, as with aging, cognitive recourses were shown to decrease [5] and attention as a spatially selective resource shows a deficit of wide attention focus [28, 29], we considered appropriately to examine this priming effect on two age groups: young and elderly. In the present study, we considered only findings concerning RTs of hand movements, as those obtained from adaptation of visual saccades were presented in another work [31]. On the base of the above mentioned findings and suggestions from known literature, we hypothesized that semantic priming would diminish hand movement RTs, more in the younger than in the older participants, but RT reduction would be smaller when the cognitive visuomotor task (directed hand movements) was preceded by visuomotor adaptation task.

Methods

Sixty healthy Bulgarians, naïve to the purposes of the experiment, were examined. Thirty of them were aged 20-26 years and thirty were aged 50-63 years. All they were right-handed with normal or corrected to-normal vision. They signed an informed consent approved by Ethics commission of the Institute of Neurobiology at the Bulgarian Academy of Sciences in Sofia which was in accordance with Helsinki Declaration of 1975. All subjects had drivers' license as the former group had 3 to 7 and the latter group had 10 to 30 years of driving practice.

Twenty young (Y) and twenty older (O) volunteers took part in three-step experiment (priming, saccadic adaptation and visuomotor hand task) and were subdivided equally into four groups with respect to the order of performance of the visuomotor hand task (VMHT): 1) immediately after priming: (groups: YP and OP), and 2) after saccade adaptation (SA) which was performed just after priming (YS and OS). The rest of the participants (ten young and ten older) were control groups (groups: YC and OC) which took part only in VMHT.

Semantic priming was performed by modification of the scrambled sentence task [2]. As improvement of saccade adaptation due to semantic priming with wide attention focus was already presented [9], we used the same scrambled sentences in the present study. Each person was given a list of 20 sentences consisting of five words as four of them had to be selected to formulate a meaningful sentence, and the fifth, non-fitting word had to be crossed out. One of the four words denoted wide focus of attention (far, approximate, global, universal, multiple, broad, open, general, common, spacious, distant, long, big, blanket, comprehensive, all-round, distributed, large, rough, total). These words were used in the study of Hüttermann et al. [16] but they were translated in Bulgarian language. The duration of the priming test was approximately 10 minutes.

The VMHT test consisted of twenty traffic scenarios, similar to those used for testing of candidate non-professional drivers that were adopted by specially designed software. Ten of them were displayed across the whole screen of a 17" computer monitor (large pictures) and ten were displayed within the central 25% of the screen area (small pictures). Viewing distance was again 40 cm. The order of appearance of big and small pictures was random and the same for all examined subjects. Most scenarios consisted of two vehicles (cars, trucks, and streetcars) and only a few scenarios – of three vehicles. Participants sat in front of the screen and were instructed to indicate as quickly as possible in what order the vehicles were allowed to pass; to this end, they had to use the computer mouse to point and click at each vehicle in the proper order. After the last click, the current traffic scenario was replaced by the next one. VMHT lasted about ten minutes.

The saccade adaptation task was a modified version of the two-step paradigm of McLaughlin [19] and was designed to adapt the direction of visually induced reactive saccades by the same manner as in many earlier and recent studies [6, 9, 14, 15]. In short: in two single-step episodes, a visual target was presented in the centre of the circle and then jumped in one of eight randomly selected directions onto the circle (0, 45, 90…., 315) deg, and returned to the centre; in following 25 double-step trials, the target jumped along the circle by -15 deg (clockwise), and then returned to the center; the procedure was finalized by two post-adaptation phases with two single-step episodes. The saccade adaptation task continued about 55 minutes. As we have already mentioned in the Introduction, the results from saccade adaptation were presented in another work.

Subjects' RTs in VMHT were measured by interactive software. The RT for the first vehicle that the subject points was determined as the delay between the picture's appearance and the moment the subject clicks the computer mouse to point the target. The RT for the second vehicle was determined as the delay between the first targeted mouse click and the second one. As pictures with three vehicles were only a few, their RTs were not analyzed. RTs of incorrect responses were discarded.

Data obtained from VMHT were analyzed by analysis of variances (ANOVA) with factors Age (young/old), Condition (after priming/after adaptation/without priming) and Picture size (large/small). Significant effects were decomposed by Fisher's LSD post-hoc test.

Results

Fig. 1 shows RT of hand movements of groups YP and OP for the first vehicle[2] in small and large pictures when VMHT were presented immediately after priming, and RTs of hand movements of both control groups – YC and OC.

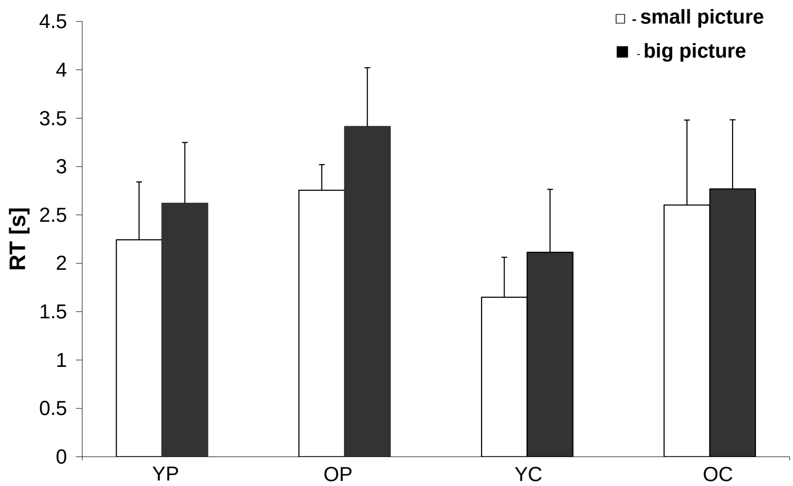

Fig. 1 Mean hand movements' reaction times of young (YP) and older (OP) participants for the first vehicle on small and large pictures in the traffic test in the following condition: Priming – VMHT – SA, and of the respective young and older control groups (YC and OC).

Symbols are across-participant means of each group, and error bars are the pertinent interparticipant standard deviations. It is noticeable from this picture that:

[2]We presented RT of hand movements only to the first vehicle as after calculations we did not found differences between hand RTs to the second vehicle.

1) RTs of primed groups (YP and OP) are longer than those of control groups;
2) RTs of both older groups (OP and OC) are longer than those of young groups (YP and YC), and
3) RT to the objects in large pictures are longer than those in small pictures.

RTs of hand movements of groups performing VMHT in the second condition, i.e., after primed saccade adaptation, are presented in Fig. 2. Symbols are across-participant means of each group, and error bars are the pertinent interparticipant standard deviations. It is visible that RTs of both age groups (YS and OS) decreased with respect to control groups (YC and OC). The differences due to age are noticeable only in the control groups (YC and OC). Again, RTs of hand movements to objects in large pictures are longer than those in small pictures.

ANOVA was applied on the results of all groups in the three experimental conditions with respect to the two sizes of pictures. Thus, it yielded significance of the factors Age ($F(1,108) = 10.4$, $p < 0.01$); Condition ($F(2,108) = 22.8.04$, $p < 0.0001$); Picture size ($F(1,108) = 7.4$, $p < 0.01$) and Age*Condition ($F(2,108) = 3.85$, $p < 0.01$).

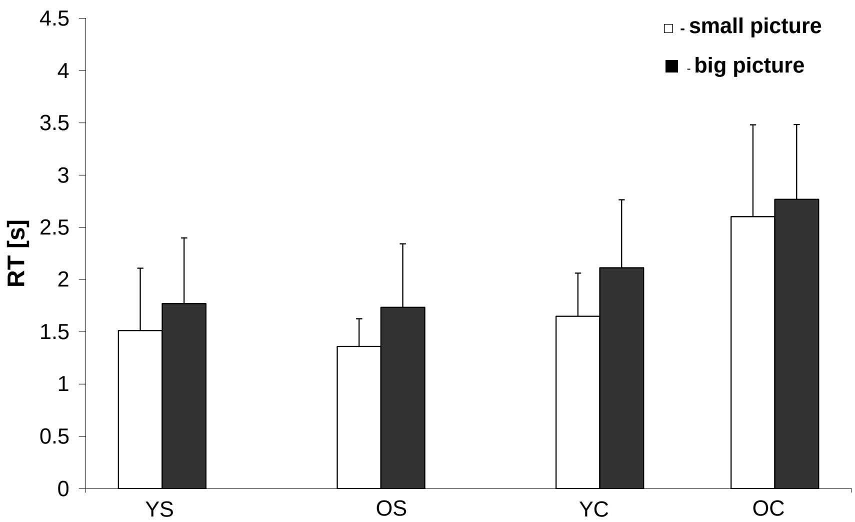

Fig. 2 Mean hand movement reaction times of young (YS) and older (OS) participants for the first vehicle on small and large pictures in the traffic test in the following condition: Priming – SA – VMHT, and of the respective control groups (YC and OC).

Post-hoc decompensation by Fisher's LSD test revealed that: hand movement RT was longer in older than in young participants; it was longest after priming and shortest after saccade adaptation and it was longer regarding the large than the small pictures. With respect to the interaction Age*Condition, post-hoc test yielded that RT of hand movement after priming in younger participants differed significantly in comparison with both without priming and after saccade adaptation while in the older persons, such a difference was found only with respect to RTs of hand movements after saccade adaptation. On the contrary, RTs of hand movement after saccade adaptation in the young participants differed significantly only from RTs after priming, while in older participants it differed from RTs in both conditions – after priming and without priming.

Discussion

The main question of this study was whether the effect of semantic priming on a cognitive visuomotor task was similar to that on a predominantly unconscious visiomotor task. As we have already showed the positive priming effect on the latter task [9], namely adaptation of reactive visual saccades, we choose an approach for revealing such similarity by priming and then exploring two tasks following one after another in different order. We expected, if the two visiomotor tasks used similarly attention resources of semantic priming, the effect of priming on hand movement RTs to be positive when the task was performed immediately after semantic priming but to be reduced after primed saccade adaptation. Surprisingly, the results obtained were just the opposite to our hypothesis: RTs of hand movements increased in the former and decreased in the latter condition.

The negative effect of semantic priming on hand RT in the immediately following VMHT was in contrast to the results obtained in an earlier work where the same words for wide attention focus and similar VMHT with a driving test were applied [16]. Although VMHT was a perceptual task, before being performed it was preceded by a decision making task, namely to point in what order the vehicles were allowed to pass in the traffic scenarios. Priming in the work of Hüttermann et al. [16] were applied as each word appeared on the screen for a determined time and then it was masked. Thus, priming itself did not need cognitive resources similar to those following VMHT. In our study, words denoting wide attention focus were presented in scrambled sentence task in which participants had to perform a lexical decision-making task of composing meaningful sentences. In fact, the semantic priming itself needs substantial cognitive resources similar to those required for decision-making in VMHT. Therefore, one could suppose that the scrambled sentence task (priming) and VMHT shared similar cognitive resources for their performance. Thus, RTs of hand movements were delayed because they were already deprived by semantic priming cognitive resources needful for decision-making in both tasks before the perceptual realization of hand movement.

The decreased hand movement RTs after saccade adaptation could be due to a positive effect of saccade adaptation on VMHT performance. A possible explanation might be different mechanisms of performance of the two tasks. Although the adaptation of reactive saccades is also a percept-dependent visuomotor act, it is a predominantly unconscious process, i.e., it is performed as a whole at subcortical brain levels [1]. Therefore, it does not need similar cognitive resources as that for the applied semantic priming and VMHT. Moreover, as moving to different directions, targets engaged a great part of the visual field on the screen, one could suppose that it might be appeared as unconscious priming for the hand movements in VMHT. Although the interaction Picture*Condition in ANOVA was not found significant, we noted, considering the results from Fisher's LSD post-hoc test, that RTs of hand movements in both large and small picture scenarios after saccade adaptation were the shortest and did not differ between them as it was found for both other conditions. This even not statistically proved result might be frail evidence supporting our supposition for a possible role of saccade adaptation as unconscious priming and it needs further experimental evidence.

We found hand movement RTs to be shorter in the large picture scenarios than those in the small ones. That seems reasonable as vision and picture visibility decrease with increasing the visual periphery involvement. A lack of significant difference between young and older participants with respect to the size of the picture could be due to the fact that the latter group had more driving practice than the former one[3].

However, in general hand movement RTs of older participants were found to be longer than those of the young ones. Although both young and older participants showed similar trends of hand movement RT changes in both experimental conditions, some differences were found which were presented by the significance of the interaction Age*Condition. At first, the result from Fisher's LSD post-hoc test showed that the RTs of older controls were longer than those of young controls that could be either due to reduced cognitive resources, i.e., delay of decision-making, or decline in the sensorimotor performance. Further, the impact of the opposite changes in hand RT found after priming and after saccade adaptation, was different in young and older participants. Thus, the enhancement of RT after priming seems to be more pronounced in the young participants than in the older ones because it differed significantly as from RT of controls as from RT after saccade adaptation while in older participants, it differed only from RT after saccade adaptation. On the contrary, reduction of RT after saccade adaptation seems to be more pronounced in older participants as in this condition RT differed significantly as from RT of control group as from that after SA while reduced RT after SA in young participants differed significantly only from that after priming. Moreover, this test also showed that after priming, RT of young persons was shorter than that of older persons while their RTs did not differ after SA. Therefore, one could suppose that the difference between hand movement RT of young and older participants was due to slower decision-making process in the latter group due to cognitive deficits caused by aging [29].

Conclusion

The present study shows that semantic priming and primed visuomotor tasks are related and the effects of the former on the latter depend on cognitive resources required for their execution. If a visuomotor task needs similar cognitive resources as semantic priming, its effect could be even negative. The present study also suggests that some visual tasks based on predominantly unconscious visuomotor processes could be used as priming for improving the performance of cognitive visuomotor tasks, e.g., driving and other professional operator activities.

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Reference

1. Alahyane N., R. Salemme, C. Urquizar, J. Cotti, A. Guillaume, J. L. Vercher, D. Pélisson (2007). Oculomotor Plasticity: Are Mechanisms of Adaptation for Reactive and Voluntary Saccades Separate, Brain Research, 1135, 107-121.
2. Bargh J. A., M. Chen, L. Burrows (1996). Automaticity of Social Behavior: Direct Effects of Trait Construct and Stereotype-activation on Action, Journal of Personality and Social Psychology, 71, 230-244.
3. Beurskens R., O. Bock (2012). Age-related Deficits of Dual-task Walking: A Review, Neural Plasticity, 131, 608-616.
4. Beurskens R., O. Bock (2012). Age-related Decline of Peripheral Visual Processing: The Role of Eye Movements, Experimental Brain Research, 217, 117-124.

[3]One-way ANOVA on driving experience with the factor Age, yielded significant difference: ($F(1,58) = 148.2$), $p < 0.001$); post-hoc test – 6.13 < 25.2 (young vs. older).

5. Bock O., M. Girgenrath (2006). Relationship between Sensorimotor Adaptation and Cognitive Functions in Younger and Older Subjects, Experimental Brain Research, 169, 400-406.
6. Bock O., G. Schmitz, V. Grigorova (2008). Transfer of Adaptation between Ocular Saccades and Arm Movements, Human Movement Science, 27, 383-395.
7. Bock O., V. Grigorova, M. Ilieva (2013). Double-step Adaptation of Saccadic Eye Movements Is Influenced by Priming with Age Stereotypies, Psychology, 4, 1014-1017.
8. Bock O., M. Ilieva, V. Grigorova (2014). Effects of Old Age and Resource Demand on Double-step Adaptation of Saccadic Eye Movements, Experimental Brain Research, 232, 2821-2826.
9. Bock O., V. Grigorova, M. Ilieva-Staneva (2017). Adaptation of Reactive Saccades Is Influenced by Unconscious Priming of the Attention Focus, Journal of Motor Behavior, 49(5), 477-481.
10. Chartrand T. L., J. A. Bargh (1999). The Chameleon Effect: The Perception-behavior Link and Social Interaction, Journal of Personality and Social Psychology, 76(6), 893-910.
11. Eimer M., F. Schlaghecken (2003). Response Facilitation and Inhibition in Subliminal Priming, Biological Psychology, 64, 7-26.
12. Eversheim U., O. Bock (2001). Evidence for Processing Stages in Skill Acquisition: A Dual-task Study, Learn Memory, 8, 183-189.
13. Gancarz G., S. Grossberg (1999). A Neural Model of Saccadic Eye Movement Control Explains Task-specific Adaptation, Vision Research, 18, 3123-3143.
14. Grigorova V., O. Bock, S. Borisova, M. Ilieva, G. Schmitz (2010). Double-step Adaptation of Saccade Directions: A Comparison of Constant and Saccade-triggered Interstep Intervals, Proceedings of the Bulgarian Academy of Sciences, 63, 157-162.
15. Grigorova V., O. Bock, M. Ilieva, G. Schmitz (2013). Directional Adaptation of Reactive Saccades and Hand Pointing Movements is not Independent, Journal of Motor Behavior, 45(2), 101-106.
16. Hüttermann S., O. Bock, D. Memmert (2014). Subliminal Primes for Global or Local Processing Influence Judgments of Vehicular Traffic, Consciousness and Cognition, 29, 230-234.
17. Kiefer M., J. J. Ortells, A. Castillo, M. Megías, A. Morillas (2016). The Semantic Origin of Unconscious Priming: Behavioral and Event-related Potential Evidence during Category Congruency Priming from Strongly and Weakly Related Masked Words, Cognition, 146, 143-157.
18. Kirilova K., P. Gatev (2018). A Complex Semi-automatic Method for Kinetic and Two-dimensional Kinematic Motion Analysis for Posture and Movement Investigation, International Journal Bioautomation, 22(1), 57-64.
19. Lavigne F., L. Dumercy, L. Chanquoy, B. Mercier, F. Vitu-Thibault (2012). Dynamics of the Semantic Priming Shift: Behavioral Experiments and Cortical Network Model, Cognitive Neurodynamics, 6, 467-483.
20. Lavigne F., L. Chanquoy, L. Dumercy, F. Vitu (2013). Early Dynamics of the Semantic Priming Shift, Advances in Cognitive Psychology, 9(1), 1-14.
21. Levesque C., L. G. Pelletier (2003). On the Investigation of Primed and Chronic Autonomous and Heteronomous Motivational Orientations, Personality & Social Psychology Bulletin, 12, 1570-1584.
22. Martens U., N. Trujillo-Barreto, T. Gruber (2011). Perceiving the Tree in the Woods: Segregating Brain Responses to Stimuli Constituting Natural Scenes, Journal Neuroscience, 48, 17713-17718.

23. McLaughlin S. C. (1967). Parametric Adjustment in Saccadic Eye Movements, Percept Psychophys, 2, 359-362.
24. Meneguzzo P., M. Tsakiris, H. B. Schioth, D. J. Stein, S. J. Brooks (2014). Subliminal versus Supraliminal Stimuli Activate Neural Responses in Anterior Cingulate Cortex, Fusiform Gyrus and Insula: A Meta-analysis of fMRI Studies, BMC Psychology, 2(1), 52, doi: 10.1186/s40359-014-0052-1.
25. Muscarella C., G. Brintazzoli, S. Gordts, E. Soetens, E. Van den Bussche (2013). Short and Long-term Effects of Conscious, Minimally Conscious and Unconscious Brand Logos, PLoS One, 8(5), e57738.
26. Ochsner K. N., J. A. Silvers, J. T. Buhle (2012). Functional Imaging Studies of Emotion Regulation: A Synthetic Review and Evolving Model of the Cognitive Control of Emotion, Annals of the New York Academy of Sciences, 1251, E1-E24.
27. Prablanc C., J. E. Echallier, M. Jeannerod, E. Komilis (1979) Optimal Response of Eye and Hand Motor System in Pointing at a Visual Target II. Static and Dynamic Visual Cues in the Control of Hand Movement, Biocybernetics, 35, 183-187.
28. Rabbitt P. (1965). Response-facilitation on Repetition of a Limb Movement, British Journal of Psychology, 56, 303-304.
29. Salthouse T. A. (1996). The Processing-speed Theory of Adult Age Differences in Cognition, Psychological Review, 103(3), 403-428.
30. Sekuler A. B., P. J. Bennett, M. Mamelak (2000). Effects of Aging on the Useful Field of View, Experimental Aging Research, 2, 103-120.
31. Staneva M., V. Grigorova, O. Bock (2018). Unconscious Semantic Priming Influences Performance of Visuomotor Tasks Differently but the Effects Are Similar in Young and Older Adults, Journal of Motor Behavior, 1-7, doi: 10.1080/00222895.2018.1545216.
32. Wang X., C. Zhi, Q. Wang (2017). Research on Wushu Actions and Techniques Based on a Biomechanical Sensor System, International Journal Bioautomation, 21(2), 199-206.
33. Williams L. E., J. A. Bargh, C. C. Nocera, J. R. Gray (2009). The Unconscious Regulation of Emotion: Nonconscious Reappraisal Goals Modulate Emotional Reactivity, Emotion, 6, 847-854.

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