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EFFECT OF GLOBAL/LOCAL ATTENTION PRIMING ON SACCADIC EYE MOVEMENT ADAPTATION IN ELDERLY AND YOUNG PERSONS: PRELIMINARY RESULTS

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Abstract

Previous studies have shown that direction adaptation of reactive saccades is similar in young and older persons, i.e. ageing is not associated with saccadic adaptation [1]. On the other hand, the existing data revealed that with ageing, the ability to divide and switch attention was impaired. As it was suggested that saccades and attention could be functionally coupled [2], the present study aimed at examining the effect of Global/Local attention priming on reactive saccade adaptation in young and older persons.

We applied Global/Local paradigm (global letters consisting of local letters) to activate respective attention mechanism just before saccadic adaptation. Double-step targets with two interstep intervals, constant (ISIc = 200 ms) and variable (triggered by subject's saccade onset – ISIv), required a −15 deg (clockwise) change of eye movements. Subjects were divided depending on attention priming and age: local – young and elderly (LY and LE) and global – young and elderly (GY, GE). The results revealed enhancement of adaptation benefit only for *global attention* induction with ISIc in both age groups.

We presume that induction with global attention improves the adaptation benefit of reactive saccades in a way that facilitates workaround strategies when appropriate conditions are available, e.g. constant interstep interval, which is open for cognitive adjustments of adaptation process. The study also supports the suggestion for coupling of visual attention and the actual saccade landing position.

Key words: motor learning, reactive saccades, ageing, attention induction

Introduction. A number of studies demonstrated that visual search was based on global-level representations that consisted of integrated objects. Thus, processes of target detection in visual search prioritized complete global shape, while fragmentary (local) object parts were more difficult to access [3, 4]. This visual attention peculiarity was described by NAVON [5] as "forest comes before the trees", i.e. our visual system prioritizes global over local levels. The Global/Local (GL) paradigm has been used to study divided attention. It was shown that ageing was associated with impairment in the ability to divide and switch attention and to inhibit irrelevant responses [6, 7].

Saccades are the most often performed eye movements in daily life, in particular – those, provoked by the sudden appearance of a peripheral visual target, which are named reactive saccades. DORÉ-MAZARS and COLLINS [2] considered saccadic adaptation as an appropriate means for answering the question whether the orientation of attention follows the adaptive shift of saccadic endpoints or it remains oriented toward the position of the initial saccadic goal. Their results showed that visual attention is directed toward the actual saccade landing position. Recent studies [1, 8] have established that adaptation benefit of reactive saccades direction of older subjects did not differ significantly from the one of younger subjects. Moreover, it was shown [8] that adaptation benefit in elderly could be increased when they were first primed with positive age stereotype using the scrambled sentence task [9].

The purpose of the present study is to examine whether and how priming with repetitive activation of global/local attention neural mechanism would effect directional adaptation of reactive saccades to displaced visual target in older and young subjects.

Material and methods. Thirty-two naïve, right-handed subjects (23 female and 9 male) with normal or corrected-to-normal vision and no motor or neurological deficits participated in this study as paid volunteers. Sixteen subjects were young (20–35 years) and sixteen were elderly (50–63 years). They signed informed consent form approved by the Ethics Committee of the Institute of Neurobiology.

Global-Local attention test. Hierarchical stimuli were used to induce global or local attention in the subjects. Global letters made up of local letters were presented in the centre of 15.4″ computer screen at a distance of 50 cm from the sitting subject in front of the screen. The stimuli were black against gray background. All global letters (A, B, E, H, P and S) were of size $13.7° \times 8°$ and consisted of local letters (a, b, e, h, p or s) with a size $0.8° \times 0.6°$. Stimulus duration was 5 s and interstimulus interval was 2 s.

Six induction episodes were performed before the beginning of the saccadic adaptation and two induction episodes were performed in the middle of the saccadic adaptation phase. Each episode consisted of sixteen global/local letter presentations. Thus, groups of younger and older persons were subdivided into two subgroups of eight according to the induced attention: Local Young (LY) and Global Young (GY), and Local Elderly (LE) and Global Elderly (GE).

In the induction phases, the subjects from the Global groups were verbally instructed to focus their attention on the global letters, disregarding the local letters, while the subjects from the Local groups were instructed to focus their attention on the local letters ignoring the global letters.

Adaptation test. Saccadic adaptation was performed by modified double-step target paradigm of McLaughlin [10]. Subjects faced a 17″ computer screen, 40 cm, ahead with their head stabilized by a chinrest. The visual target was presented along a circle of 11 cm radius in four possible directions: 0°, 90°, 180°, and 270° (0° is rightward of the centre). A gray square of size 1° served as a target against a white background. In single-step trials the target remained stationary for 760–1500 ms in the centre and then appeared at one of the four randomly selected directions for 760 ms. In double-step trials, the target was displaced by −15° (clockwise) along the circle and was extinguished 640 ms later. Depending on the mode of the target displacement triggering, i.e. either by subject's saccade onset (variable interstep interval – ISIv) or by constant interstep interval (ISIc) = 200 ms, all groups were subdivided into groups of four subjects. This separation was done for two reasons: on the one hand, we have shown [11] similar saccade adaptation benefits for groups with constant (200 ms) and saccade triggered interstep interval, but on the other hand, it was proposed that adaptation could be modified by intra-saccadic target step due to priming attention contribution [12].

Eye movements were registered by electro-oculography (DC-EOG) with a bandpass filter of 0.08–100 Hz. The signals were calibrated each five episodes, digitized with a resolution of 0.01deg/bit and a sampling rate of 100 Hz, and were stored for later analysis.

The test started with two baseline single-step episodes followed by an adaptation phase of twenty-five double-step episodes and by two final single-step episodes. Each episode consisted of twenty trials.

The collected data were analyzed by custom-designed interactive software, which determined *saccade direction* as angular difference between first target step and primary saccade direction in the plane of the screen and reaction time as an interval between appearance of the target and saccade movement onset, subtracting each baseline values in order to facilitate comparisons across subjects.

Results. The baseline directions of the eye movements were similar in all groups (LY, LE, GY and GE). This was confirmed by one-way ANOVA with between-factor Group which yielded insignificant effect ($p > 0.05$). Adaptation directions of all groups were also similar as was confirmed by repeated-measured ANOVA which established significance only for the within-factor *Episode* ($F(24, 504) = 7.2$, $p < 0.001$) but insignificance of the between-factor *Group*.

Fig. 1 presents adjusted to baseline adaptation episodes of saccades in groups GY and GE, and LY and LE which were subdivided depending on ISI. The baseline directions of the eye movements were similar in all groups as was confirmed by one-way ANOVA with between-factor Group which yielded insignificant effect ($p > 0.05$). Adaptation curves of both groups GY and GE showed a difference between ISIc and ISIv (Fig. 1*A*), while such a difference was not visible for groups LY and LE (Fig. 1*B*). Indeed, repeated measured ANOVA on saccadic adaptation after priming with global attention only yielded a significant effect for *Interval* ($F(1, 9) = 6.3$, $p < 0.05$) and *Episode* ($F(24, 216) = 3.04$, $p < 0.001$), but insignificant effect for *Age* although ISI difference between ISIc and ISIv of elderly persons was larger (-7.36 vs. -3.3) than that of younger persons (-4.2 vs. -2.4).

Aftereffect values of all groups were comparable and a successful de-adaptation from the first to the second episode was confirmed by ANOVA that revealed a significant effect only for the within-factor *Episode* ($F(1, 24) = 7.41$, $p < 0.05$) but insignificance for between-factors *Group* and *Interval*.

The mean baseline reaction times of saccades were 174.2 ms and 175.1 ms for groups LY and GY, and 210.1 ms and 201.2 ms for groups LE and GE, respectively. ANOVA with the factor *Group* yielded significance ($F(3, 28) = 7.18$, $p < 0.01$) as Post-hoc test revealed that RTs of both groups of elderly were larger than RTs of both groups of younger subjects.

ANOVA of adjusted to baseline RTs yielded significance of the factors *Episode* ($F(24, 504) = 1.78$, $p < 0.05$), *Interval* ($F(1, 21) = 12.6$, $p < 0.01$) and *Episode* Interval* ($F(24, 504) = 1.91$, $p < 0.01$). Post-hoc test showed that RT decreased by 12.6 ms during adaptation with ISIc but by 4.9 ms during adaptation with ISIv. Although, the factor *Group* was not found significant, the biggest RT reduction was found in group GE with ISIc (-13.4 ms vs. 0.44 with ISIv).

Discussion. The results from saccadic adaptation establish a positive effect of *global* attention induction on saccade adaptation for *both* age groups. Thus, when global attention level was preliminarily activated, it improved saccadic adaptation which coupled with focus of attention in regard to actual saccade landing position [2, 12].

However, this positive effect of global attention on adaptation was revealed *only* when reactive saccades were adapted with constant ISI, i.e. the effect of priming was *restricted* by the intrasaccadic interval. Adaptation is thought to reflect two processes, sensorimotor recalibration and workaround strategies. As the latter includes anticipations and cognitive adjustments, one can presume that double-step adaptation with *constant* ISI facilitates awareness as target timing is controlled by the experimenter rather than by the subjects. This finding from the present study suggests that adaptation with ISIc is likely open for cognitive adjustments. Indeed, dominant adaptation benefit with ISIc of young and older groups and similar aftereffects of all groups suggests an increased strategy contribution probably due to preliminary global attention induction.

The frontal lobe hypothesis of ageing suggests that cognitive functions such as working memory and attention [13–15] supported by the frontal and prefrontal cortices are more susceptible to age related decline than those functions that rely on posterior and subcortical areas [16, 17]. This hypothesis could explain why

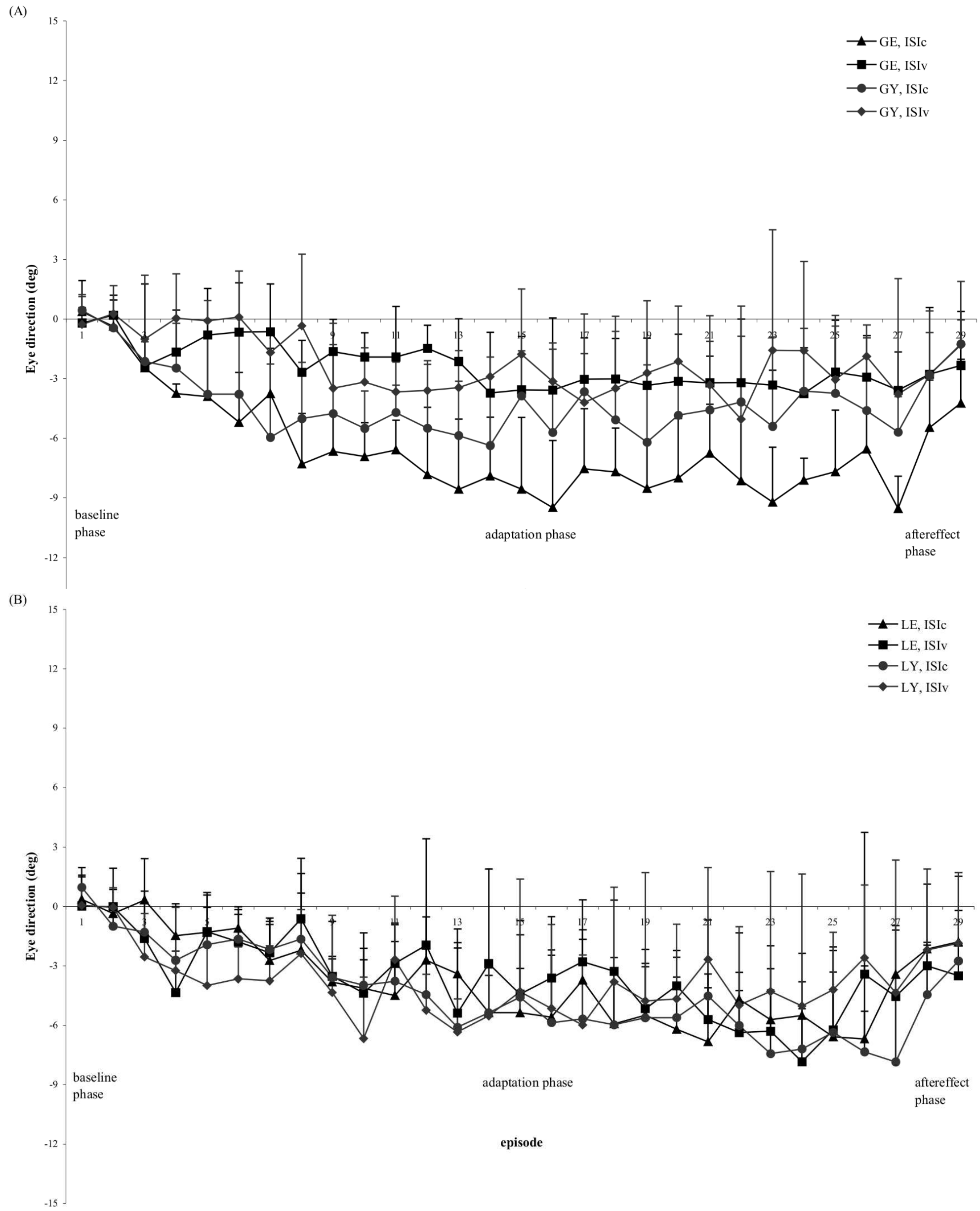

Fig. 1. Eye directions of groups GE, GY, LE and LY who were primed with global (*A*) and local (*B*) attention, and with constant-ISIc or variable-ISIv: 1–2 episodes – baseline phase; 3–27 – adaptation phase; 28–29 – aftereffect phase. Each symbol is the across-subject mean of one episode and each error bar the pertinent intersubject standard deviation

adaptation of reactive saccades which rely mostly on subcortical structures was found similar for older and younger subjects in a recent study [1] and also in the present study. A tendency for a predominant effect of global induction on saccade adaptation was observed in elderly with respect to *both* saccadic parameters direction and reaction time. The latter parameter is thought as more influenced by central mechanisms as saccadic latency can be viewed as decision time, and, as with any decision process, can depend on different cognitive influences, e.g. strategies and attention. This suggests that adaptive processes in elderly, may be more susceptible to central influences than those in younger persons but further research is needed to definitely establish the interplay between global attention and saccadic adaptation in ageing.

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