Action Video Games Improve Direction Discrimination of Parafoveal Translational Global Motion but not Reaction Times

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Abstract

Playing action video games enhances visual motion perception. However, there is psychophysical evidence that action video games do not improve motion sensitivity for translational global moving patterns presented in fovea (Hutchinson & Stocks, 2013). This study investigates global motion perception in action video game players (AVGPs) and compares their performance to that of non-action video game players (NAVGPs) and non-video game players (NVGPs). Stimuli were random dot kinematograms (RDKs) presented in the parafovea. Observers discriminated the motion direction of a target RDK presented in one of the four visual quadrants. AVGPs showed lower motion coherence thresholds than the other groups. However, when the task was performed at threshold, we did not find differences between groups in terms of distributions of reaction times. These results suggest that action video games improves visual motion sensitivity in the near periphery of the visual field, rather than speed response.

Keywords: Global translational motion, action video games, parafoveal stimuli, reaction times

Introduction

Action video games (AVGs) have peculiar characteristics that make them important for psychological research. In particular, they are characterised by unpredictable transient events (both spatially and temporally) and fast moving objects. This implies a high degree of perceptual, cognitive and motor load. For example, multiple items need to be tracked and kept in visual short-term memory, multiple actions must be planned and quickly executed. Additionally, AVGs promote near peripheral and peripheral processing (Green, Li, & Bavelier, 2010a). In fact, it has been shown that playing AVGs enhances a range of cognitive abilities including working memory (Gong et al., 2016), spatial cognition (Feng et al., 2007), response selection and execution (Hutchinson, Barrett, Nitka, & Raynes, 2016), object tracking (Green & Bavelier, 2012), visual selective attention (Chisholm & Kingstone, 2015; Green & Bavelier, 2003) and motion perception (Green, Pouget, & Bavelier, 2010b; Hutchinson & Stocks, 2013). In addition, training on AVGs improves reading abilities in children with developmental dyslexia (Franceschini et al., 2013; Franceschini et al., 2015; Gori, Seitz, Ronconi, Franceschini, & Facoetti, 2015) (see Karimpur & Hamburger (2015) for a review on the role of AVGs in psychological research).

Hutchinson and Stocks (2013) found that action video game players have lower coherence threshold for radially moving patterns (e.g., contracting vs. expanding motion), but not for translational or rotational moving patterns presented in the fovea. Furthermore, the authors showed that for radial motion, action video game players exhibit lower coherence thresholds for contracting than expanding moving patterns. The results pointed out an asymmetry in optic flow components for action video gamers, probably due to the fact that this type of motion is highly trained in action video gamers, especially when players have to move backwards their character to avoid shooting and escape enemies.

In this study we investigated the perception of translational global motion with stimuli presented in parafovea. The performance of action video game players was compared to that of non-action video game players and a control group of non-video game players. Differently from the previous studies, all the observers were initially trained until they achieved an accuracy of ~90% in motion direction discrimination of parafoveal stimuli. This was done to match the initial performance of the three groups. In the second phase of the experiment we estimated the motion coherence thresholds for 79% correct motion direction discrimination (Hutchinson & Stocks, 2013). In the third phase, observers performed three blocks in discriminating motion direction at threshold. In these latter blocks we also measured reaction times. This would allow a stricter comparison of reaction times between the groups.

The results showed that motion coherence thresholds for action video game players were significantly lower than motion coherence thresholds of the non-action video game players and controls. Interestingly, we did not find a significant difference between the control group and non-action video game players. However, we did not find differences in terms of reaction times among the three groups.

Methods

Apparatus

Stimuli were displayed on a 24-inch IPS LED Dell P2414H monitor with a refresh rate of 60 Hz. Stimuli were generated with Matlab Psychtoolbox (Brainard, 1997; Pelli, 1997). The screen resolution was 1920 x 1080 pixels. Each pixel subtended 1.7 arcmin. Observers sat in a dark room at a distance of 57 cm from the screen.

Participants

Twenty-four naïve participants took part voluntarily to the experiment. There were three groups: one control group (N=8) with no previous experience in video game playing (NVGPs), one group (N=8) of non-action video game players (NAVGPs) (e.g., Sims and FIFA) and one group (N=8) of action video game players (AVGPs) (e.g., Call of Duty, Battlefield, Fallout, Far Cry, Grand Theft Auto). In order to be considered a video game player the participant needed to have played a minimum of 3-4 days a week in the past six months for a minimum of two hours each day, whilst a non-video game player had played no video game in the past six months. In order to allocate the video game players into NAVGP and AVGP groups, we used the questionnaire from Rosser et al. (2007). The questionnaire is useful to determine the genres of game played and make sure that video game players played for a minimum of two hours a day on one genre (action or non-action), and had not played any hours on the opposite genre. This is to make sure that video game players were specifically experienced in either action or non-action video games.

All participants had normal or corrected to normal visual acuity. Viewing was binocular. Methods were carried out in accordance with the Declaration of Helsinki (1964). This study was approved by the Ethics Committee of the University of Lincoln. Written informed consent was obtained from each participant prior to the enrolment in the study.

Stimuli

Stimuli were global motion random dot kinematograms (RDKs) made up by 100 white dots (diameter: 0.15 deg) presented within a circular aperture with a diameter of ~8 deg (density: 1.99 dots/deg^2). The dots' Weber contrast was set at 0.9 and moved on a grey background. The motion sequence was computed as follows: on the first frame of each RDK, dots were randomly positioned within the circular window and were displaced by 0.22 deg on each subsequent frame, producing a speed of 13.3 deg/s. Dots had a limited lifetime; that is, after 83 ms each dot vanished and was replaced by a new dot at a different randomly selected position within the circular window. Dots appeared asynchronously on the display. Every four motion steps in the global motion sequence each dot had an equal probability of being selected as a signal dot (Morgan & Ward, 1980; Newsome & Paré, 1988). This was implemented to minimize the presence of local "motion streaks" (Geisler, 1999) that could provide cues for direction discrimination. In addition, moving dots that travelled outside the circular window were also replaced by a new dot at a different randomly location within the circular window, thus always maintaining the same density. Dots were either constrained to move globally along translational trajectories (signal dots) or were positioned in new locations, randomly selected within the circular window, on each successive frame of the sequence (noise dots) (Scase, Braddick, & Raymond, 1996). Each RDK consisted of a 12-frame global motion sequence (i.e., 200 ms) in which a certain percentage of dots were signal dots (i.e., those that moved in the coherent direction), whereas the remaining dots were noise (i.e., those that were positioned in randomly selected locations). We employed such stimulus duration and limited dot lifetime to prevent both covert attentional tracking of the stimulus motion direction and eye movements toward the stimuli (Martinez-Conde, Macknik, & Hubel, 2004; Wright & Ward, 2008). The spatiotemporal characteristics of the RDKs matched those reported in a previous investigation on global motion and ensure that false matches across successive frames were negligible and the correspondence problem was minimized (Pavan, Langgartner, & Greenlee, 2013; Stevens, McGraw, Ledgeway, & Schluppeck, 2009; Williams & Sekuler, 1984). We used four RDKs, one in each visual quadrant, to assess parafoveal motion discrimination and increase the perceptual processing required to perform the task.

Procedure

Training sessions (phase 1)

Observers performed a number of training sessions in order to ensure the same starting accuracy in direction discrimination for all the three groups. In particular, participants performed a number of training blocks necessary to get a percentage of correct responses between 90% and 95% in discriminating the motion direction of a 100% coherently moving RDK. A single training block consisted of 40 trials in which after an initial fixation point of 1s, four RDKs were presented in each visual quadrant. RDKs were presented in the parafovea. The distance from the central fixation point to the center of each RDK was 7.5 deg. Three of the RKDs had no coherent motion (0% coherence), with dots randomly positioned on each frame inside the circular window (i.e., random placement noise; Scase et al., 1996), whereas one RDK contained dots moving coherently in one of eight possible directions (i.e., upwards, downwards, leftward, rightward, up-right [45°], up-left [135°], down-right [315°], down-left [225°]) (Figure 1). In each block, there were 5 repetitions of each motion direction. Observers reported the motion direction of the coherent RDK using one of eight designated keys of the keypad of a standard computer keyboard. The spatial position of the target was randomized on each trial and could be presented in any of the visual quadrant. After the stimulus presentation there was a 1.5s blank interval in which only the central fixation point was presented.

[FIGURE 1 ABOUT HERE]

Motion coherence threshold (phase 2)

The second phase of the experiment was the same as the previous one, with except that we estimated individually for each observer the motion coherence threshold in discriminating the direction of a parafoveal globally moving RDK. The motion sequence was the same as described in the stimulus phase but the coherence of the target RDK was manipulated using a Maximum Likelihood Procedure (MLP) (Grassi & Soranzo, 2009; Green, 1990, 1993). Participants performed five runs with 32 trials each. The final coherence threshold producing 79% of correct motion direction discrimination was estimated by averaging the output of the five runs.

Reaction times (phase 3)

In the last phase of the experiment, observers performed three blocks (40 trials each). This phase was identical to the first phase with except that the coherence of the target RDK was set at the individual motion coherence thresholds estimated in phase 2. The aim of the third phase was to measure reaction times at an accuracy level of 79% in motion direction discrimination.

Data analysis

Proportion of correct responses and motion coherence thresholds were analysed using a Kruskal-Wallis test. Post-hoc comparisons were performed using the Mann-Whitney U test. Multiple comparisons were corrected using a false discovery rate (FDR) at 0.05 (Benjamini & Hochberg, 1995). We also used one-sample Wilcoxon signed rank tests with a FDR at 0.05 to assess whether accuracies differed from medians of 90% and 79% (see the results section).

We also analysed the distribution of the reaction times for correct trials only. For each observer, outliers reaction times were identified and filtered out using the median absolute deviation (MAD) around the median with a cut-off of 3 (Leys, Ley, Klein, Bernard, & Licata, 2013; Rousseeuw & Croux, 1993). Correct-RT distributions were approximated by 5 quantiles, evenly spaced between 0.1 and 0.9. An ex-Gaussian distribution was then fitted to the RT distribution of each participant. The ex-Gaussian probability density function is defined as:

$$f\left(x \mid \mu,\sigma,\tau\right)=\frac{1}{\tau}\exp\left(\frac{\mu}{\tau}+\frac{\sigma^2}{2\tau^2}-\frac{x}{\tau}\right)\Phi\left(\frac{x-\mu-\frac{\sigma^2}{\tau}}{\sigma}\right) \qquad \text{Eq. 1}$$

where the exponentials function (exp) is multiplied by the cumulative density of the Gaussian function (Φ), μ and σ correspond to the mean and standard deviation of the Gaussian component, and τ is the mean of the exponential component, which regulates the skewness of the distribution (Lacoutre & Cousineau, 2008; Luce, 1986). χ^2 goodness-of-fit tests were computed for each participant and all curve fits passed the goodness-of-fit test.

Results

Figure 2 shows the results of the experiment. For the training phase, NVGPs, NAVGPs, and AVGPs performed respectively a total of 27, 33 and 20 training session to achieve an accuracy of 90%. A Kruskal-Wallis test did not report a significant effect of the group on the baseline accuracies (χ^2 = 0.61, *df* = 2, *p* = 0.74). A one-sample Wilcoxon signed rank test was used to assess whether the median of each group was significantly different from a median accuracy of 90%. The results showed that the accuracy of the three groups were significantly higher than a median of 90% (adjusted-*p* = 0.027 using a FDR of 0.05) (NVGPs = 0.93 [SEM=0.007], NAVGPs = 0.94 [SEM=0.012], AVGPs = 0.94 [SEM=0.012]). Therefore, after the initial training sessions the three groups could discriminate with the same level of accuracy the motion direction of parafoveal translational moving stimuli.

Figure 2A shows the motion coherence thresholds estimated for the three groups. A Kruskal-Wallis test reported a significant effect of the group (χ^2 = 13.29, *df* = 2, *p* = 0.001). Multiple comparisons were conducted using a Mann-Whitney U test with a FDR of 0.05. The Mann-Whitney U test did not report a significant difference between NVGPs and NAVGPs (*Z* = -1.36, adjusted-*p* = 0.172), but reported a significant difference between NVGPs and AVGPs (*Z* = -3.05, adjusted-*p* = 0.0045) and a significant difference between NAVGPs and AVGPs (*Z* = -3.0, adjusted-*p* = 0.0045).

A Kruskal-Wallis test conducted on the accuracies obtained in the phase 3 of the experiment did not report a significant effect of the group (χ^2 = 0.167, *df* = 2, *p* = 0.92). In addition, one-sample Wilcoxon signed rank tests did not report a significant difference between the accuracy of each group and a median of 79% (NVGPs: *p* = 0.58; NAVGPs: *p* = 0.78; AVGPs: *p* = 0.99). This confirms that observers' performance was at threshold.

Figure 2B shows the ex-Gaussian distribution fitted to the RT data from the three groups (left panel) and the parameters μ, σ, and τ (right panel). For demonstrative purposes, the represented curves were obtained by fitting the ex-Gaussian distribution to filtered RT data of all the participants of each group. However, the estimation of parameters μ, σ, and τ was obtained by fitting the ex-Gaussian distribution individually for each subject (see the data analysis section). In order to test for differences between RTs of the three groups, we performed a Kruskal-Wallis test for each parameter. The Kruskal-Wallis did not report a significant effect of the group for μ (χ^2 = 2.15, *df* = 2, *p* = 0.35), σ (χ^2 = 0.55, *df* = 2, *p* = 0.76), and *τ* (χ^2 = 3.70, *df* = 2, *p* = 0.157). Additionally, in order to determine whether there was a statistically significant trend of lower RTs with action video games, we performed a Jonckheere-Terpstra test for ordered alternatives (NVGPs > NAVGPs > AVGPs) on the parameter μ. The test showed that there was not a significant trend of lower RTs for action video games (*JT* = 1.48, *p* = 0.139). The same test was also conducted on the other parameters (σ: *JT* = 0.634, *p* = 0.53; τ: *JT* = 1.48, *p* = 0.139).

[FIGURE 2 ABOUT HERE]

Discussion

In this study we investigated global motion perception of parafoveal translational stimuli in three groups of observers; action video game players (AVGPs), non-action video game players (NAVGPs) and a control group of non-video game players (NVGPs). Differently to that reported by Hutchinson and Stocks (2013), we found that AVGPs exhibit greater motion sensitivity (i.e., lower motion coherence thresholds) then the other groups. It seems that this advantage for translational global motion in AVGPs is apparent only when stimuli are presented in the parafovea. In fact, Hutchinson and Stocks (2013) using a similar motion sequence did not find higher sensitivity for translational global motion when stimuli were presented in the fovea. This result can be explained in terms of improved capacity, improved spatial distribution (Green & Bavelier, 2003), and higher spatial resolution (Green & Bavelier, 2007) of visual attention in AVGPs. This would influence AVGPs' ability to track multiple objects, identify and select a target among distractors, and reduce crowding regions for peripheral moving stimuli (Green & Bavelier, 2007; Green et al., 2010a). Besides, it has been recently demonstrated that AVGPs also exhibit enhanced perceptual templates that facilitate the rapid learning of task-relevant statistics, while excluding task-irrelevant sources of variability (Bejjanki et al., 2014).

The specific direction of translational motion might also be important. For example, it might be that Hutchinson and Stocks (2013) did not find any differences between AVGPs and NVGPs for translational motion because they only assessed coherence thresholds for up and down motion (i.e., vertical axis of motion). In order to test for asymmetries between different axis of motion, we conducted an additional analysis on the data of phase three of our experiment. In particular, we analysed the accuracies separately for each axis of motion (i.e., vertical, horizontal and the two diagonal axis) and for each group. A mixed ANOVA did not report any significant effect or interaction (group: $F_{2,21} = 0.014$, $p = 0.98$, $p\eta^2 = 0.001$; axis of motion: $F_{3,63} = 0.95$, $p = 0.42$, $p\eta^2 = 0.043$, interaction axis of motion x group: $F_{6,63} = 0.87$, $p = 0.52$, $p\eta^2 = 0.076$), suggesting that there are no evident asymmetries between the different axis of motion employed. However, this does not mean that motion sensitivity is the same for all axis of motion. In fact, there is psychophysical evidence that motion discrimination thresholds depend on the absolute direction of motion (Ball & Sekuler, 1982; Gros, Blake, & Hiris, 1998). Therefore, further experiments are necessary to assess whether the advantage exhibited by AVGPs is specific to certain motion trajectories, as for optic flow components (i.e., contracting/expanding motion). Indeed, Hutchinson and Stocks (2013) reported that AVGPs exhibited greater sensitivity for complex moving patterns at both foveal and parafoveal locations. This can be explained by the fact that in action video games optic flow components are more predominant than translational motion directions.

For reaction times Green et al. (2010b) showed that in a motion direction discrimination task with centrally presented stimuli, AVGPs were faster than NVGPs in responding to the direction of the motion sequence. This facilitation was more evident for low motion coherence levels than high levels. However, the accuracy in judging the direction of the motion pattern was the same in the two groups. In our study we did not find any evidence of faster reaction times in discriminating the motion direction of parafoveal stimuli. Looking at the data of Green et al. (2010b) (Figure 1), at approximately 79% of accuracy (corresponding to a motion coherence of ~13%) they found a difference in reaction time of ~200 ms between AVGPs and NVGPs. In our study at the same accuracy level we found a (non-significant) difference of 56 ms, and a (non-significant) difference of 18.6 ms between NAVGPs and NVGPs. This discrepancy could be due to the fact that the parafoveal stimuli used may require longer latencies in response selection and implementation (Ando, Kida, & Oda, 2002) and that the practice on action video games may be not sufficient to speed up response times for such a complex peripheral task. van Ravenzwaaij, Boekel, Forstmann, et al. (2014) in order to assess whether action video games improve speed of information processing, trained their observers with action and non-action video games up to 20 hours. However, they did not find any significant improvement in accuracy and reaction times for observers trained with an action video game in a two-alternative motion direction discrimination task with stimuli presented at the fovea. These results may suggest that the benefit of training with action video games is evident after prolonged periods of playing to different action video games and not just 20 hours, though Green and Bavelier (2003) showed that after 10 hours training with an action video game, observers showed improvement in visual attentional tasks such a reduction of the attentional blink and higher accuracies at the useful field of view.

In general, our findings suggest that practice with action video games improves sensitivity to visual translational global motion when stimuli are presented in the near periphery of the visual field, but facilitation on reaction times was not evident. Besides, the results of Hutchinson and Stocks (2013) indicate that when translational global moving stimuli are presented in fovea accuracy and motion sensitivity are not affected, though this only applies to up vs. down motion. However, for foveal stimuli, the advantage on reaction times seems to be evident (Green et al., 2010b).

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FIGURE CAPTIONS

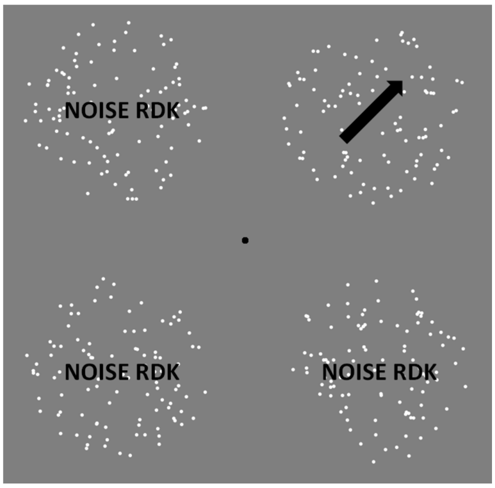

Figure 1. Stimulus used in the experiment. Only one RDK contained coherent global motion (top-right RDK moving at 45° in the example), whereas the other patches were noise RDKs.

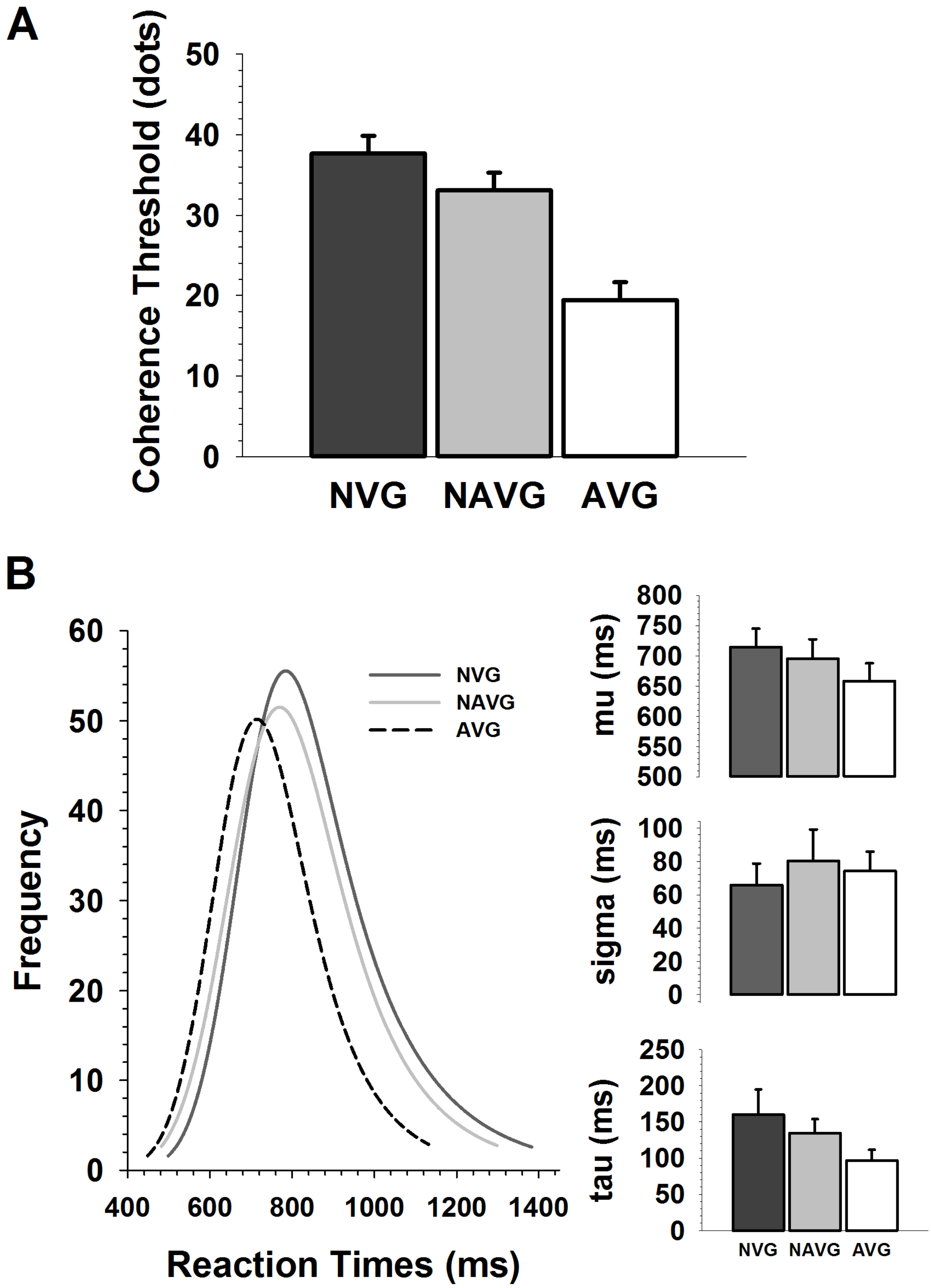

Figure 2. (A) Mean motion coherence thresholds (in dots) for NVGPs, NAVGPs and AVGPs. (B) Left panel: ex-Gaussian distributions fitted to the RT data of the three groups. Right panel: mean parameters of the ex-Gaussian distribution, μ, σ, and τ. Error bars ±SEM.