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Individual response times as a window into internal planning processes

| Research

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Abstract: Individuals with attention deficit hyperactivity disorder (ADHD) experience motor deficiencies during their daily routine and difficulties in motor planning. Internal processes of motor planning influence the response time of starting a reaching movement following different planning intervals. In this preliminary study, we compared motion onset patterns following different planning intervals of eight participants diagnosed with ADHD with those of healthy participants from a previous experiment. The minimum response time in participants with ADHD was shorter than that of the healthy participants, possibly indicating less effective maintenance of the motor plan in working memory.

Keywords: Motor planning; attention deficit hyperactivity disorder; response time; reaching movement.

1. Introduction

Reaching movement reaction time (RT) has been shown to be an indication of internal processes of motor planning [1-3]. In a previous timing onset pattern experiment [4], we showed that after different planning intervals, individuals have different onset times for reaching movements. Typically, these RT times have an overall U-shaped pattern: RT shortens when more planning time is made available but lengthens again as planning time further increases. We suggested that the shortening of RT indicates a matureness of a motor plan while the later lengthening indicates decaying of the motor working memory.

Individuals diagnosed with attention deficit hyperactivity disorder (ADHD) exhibit motor deficiencies during their daily routine, and difficulties in fine and gross motor skills have also been described [5−8].

As RT may be an indication of internal processes of motor planning and memory, we attempted to investigate whether individuals with ADHD display different onset time patterns compared to those found in the general population. In a previous motor planning experiment [9], we have shown that individuals with ADHD do not display a shortening of onset time to the same extent as controls when provided with additional planning time. In this preliminary study, we compared the time patterns of eight participants with a diagnosis of ADHD to the onset times found in the previous timing onset pattern experiment.

2. Methods

2.1. Participants

The study group comprised eight participants aged 20−31 years (mean 26.3, standard deviation 4.03) with an ADHD diagnosis. Inclusion criteria included an age over 18 years and a clinical diagnosis of ADHD made by a clinician recognized by the Technion Institute of Technology. Participants on ADHD medication discontinued their medication at least 24 hours prior to testing. Informed consent was received from all participants. The study was approved by the Technion ethics committee.

2.2. Apparatus and procedure

For the experiment, participants manipulated a pen-like stylus of a phantom robotic arm. The experimental setting was projected to a semi-transparent horizontal mirror. Participants held the pen like a stylus at a fixation point and were trained to initiate a movement towards a target at the fourth of four consecutive tones. At each trial, one of four possible targets was presented randomly, while a row of obstacles was always visible between the start position and the target (see Figure 1).

The selected target appeared at one of two time intervals, either short or long, before the last tone. In the short interval, the target appeared 25 ms before the last tone – an interval that was found to be insufficient for a mature motor plan. In the long intervals, the target appeared for one of four possible durations (250/350/450/550 ms) before the last tone; these intervals were found to be sufficient for a mature motor plan. The experiment included four blocks, one for each long planning interval, in which short and long trials were mixed. Blocks were displayed in a random order.

Figure 1. Experimental setting. Participants led the stylus from a starting point towards one of four possible targets (red), avoiding the obstacles (blue).

3. Results

3.1. U-shape pattern for participants with ADHD

In the timing onset pattern experiment, we were able to identify a maximum RT in regard to the short planning interval of 25 ms, a minimum RT in regard to the shortening of RT as more planning time was provided, followed by a further rise in RT, which we identified as a second maximum RT. This resulted in an overall U-shaped pattern.

In the data recorded for participants with ADHD, we were able to identify these three time points for all eight participants (see Figure 2).

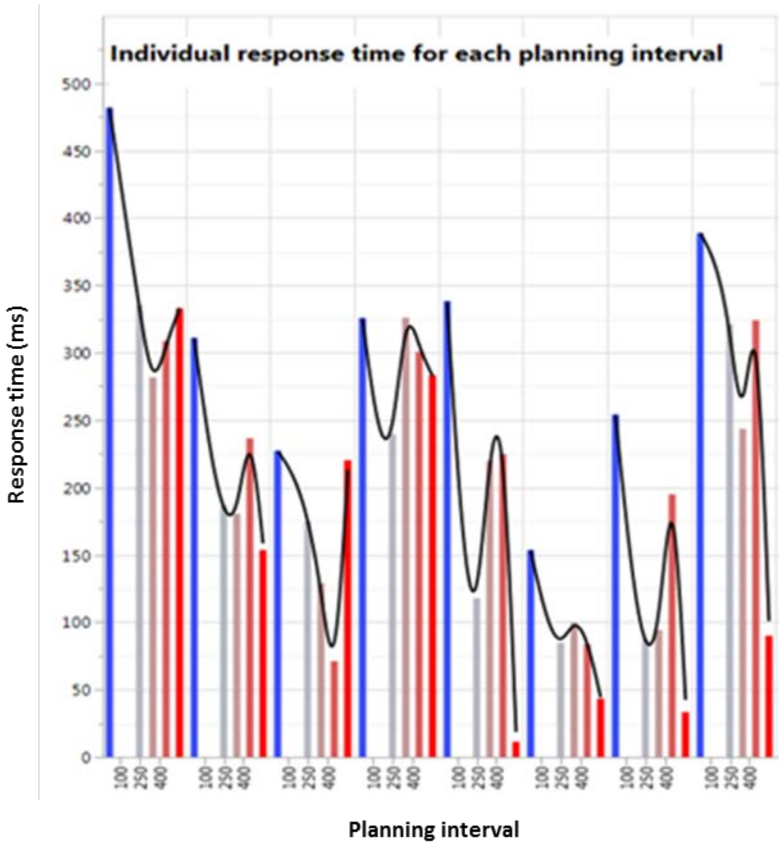

Figure 2. Onset movement times for the different planning intervals of 25, 250, 350, 450 and 550 ms for all participants with an ADHD diagnosis. A U-shape pattern can be observed.

3.2. U-shape differences between ADHD and healthy participants

In view of the observed U-shape patterns found in the timing onset patterns experiment, we sought to explore whether the individual U-shape min-point differed between ADHD participants and healthy participants and, if so, whether ADHD participants' min-point is shorter or longer. The min point represents the length of time the target is displayed that allows a minimum RT. We compared the RT of ADHD participants with the data collected in the timing onset patterns experiment. Sixteen participants aged 22–45 years (mean 32.1, standard deviation 6.9), with normal or corrected vision, no known motor problems or mental problems, and no existing diagnosis of ADHD participated in the timing onset patterns experiment.

We performed a post-hoc comparison between the individual min-points of the two groups, using a two-sided t-test. The results show that the average U-shape minimum point is longer for healthy participants (393.75 ± 22.26 ms) than that of ADHD participants (325.0 ± 31.47 ms), although the difference between the groups was not found to be statistically significant ($t(22)=1.78$, $p=0.088$), possibly due to the small number of participants (see Figure 3).

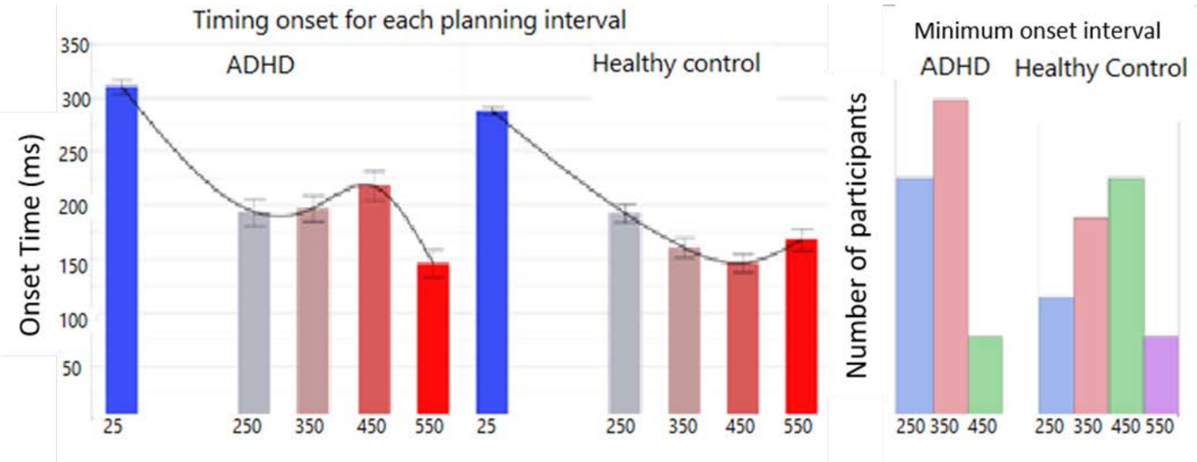

Figure 3. Left: pattern of onset times for each planning interval for ADHD group compared with the pattern found in the timing onset patterns experiment for the healthy group. **Right:** Histogram of individual shortest onset time planning interval. In the ADHD group, the largest number of participants had a minimum RT following the 350-ms interval. For the healthy participants, the largest number of participants had a minimum RT after the 450-ms interval.

4. Discussion

Some overall differences can be seen between the RT patterns of participants with ADHD and the healthy control group. In the ADHD group, RT was longer for the short planning condition. In the healthy control group, RT was found to shorten as more planning time was made available. In the ADHD group, RT also shortened but not to the same extent. Interestingly, the individual U-shape time for minimum RT for participants diagnosed with ADHD was mostly shorter than that of the healthy participants, with an average of 393.7 ms in the healthy group and 325 ms in the ADHD group.

We suggest that this time discrepancy may be related to disturbances in the frontal hippocampal network previously found in individuals with ADHD [10-12], which may be implicated in a difficulty in keeping the encoded population response of a motor plan active. The existence of such a buffer has been proposed by Jensen [13], suggesting that recently active items can be maintained in a temporally compressed buffer within the hippocampal theta oscillation, such that cells representing each item can fire sequentially within the short time range of long-term potentiation.

In terms of the individual motor preparation time window, this could indicate that participants with ADHD have a shorter time-window for minimum RT, so that the maximum preparation time-span which still facilitates the motion-onset RT for ADHD participants is shorter than that of healthy participants. Further, it can be seen that the actual starting time is more delayed for ADHD participants. This may seem surprising when we consider the impulsive nature of ADHD participants but is in accord with our previous experiment [9] and with other reports on slowness of response time, and we consider it to be an indication of an incomplete motor plan.

5. Conclusion

It appears that the typical pattern of onset times, following different planning intervals may be different between healthy participants and individuals diagnosed with ADHD. This pattern can serve as a window into internal processes such as maturity of motor planning and disturbances in the prefrontal cortex-hippocampal network.

Conflict of interest

The authors declare no conflict of interest.

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