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RESEARCH ARTICLE

Time-based event expectancies in children with Autism spectrum disorder

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Abstract Here, we studied the time-based event expectancies in children with Autism spectrum disorder. Nine children with Autism spectrum disorders and ten (6–11 years) typically developing children participated. In a choice-response task with two different pre-target intervals, participants had to indicate the left or right direction of a target stimulus. The target was predicted by the duration of the pre-target interval with 80% validity. We found that, in children with Autism spectrum disorder, in contrast to typically developing children, the formation of time-based event expectancies was restricted to the relatively longer pre-target interval. This pattern is rather typical for healthy young adults. These findings indicate that children with Autism spectrum disorder are able to form time-based event expectancies, and that, similar to healthy young adults, longer pre-target intervals enable them to make more optimal temporal predictions.

Keywords Temporal cognition · Associative learning · Time-based expectation · Autism spectrum disorder

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Introduction

Autism spectrum disorder (ASD) is neurodevelopmental disorder that is characterized by dysfunctions in social communication and social interaction, accompanied by a restricted range of interest and stereotyped, repetitive behaviors (American Psychiatric Association 2006; Frith 2003). Although these dysfunctions are typically considered as ''core'' deficits in ASD individuals, clinical reports suggest that subjects with ASD have another major deficit—a timing deficit (Boucher 2001). According to some views, the interval timing deficit, i.e., a deficit in the processing of temporal duration, may even contribute to diagnostic symptoms, such as stereotypic behaviors, since stereotypic behaviors are sometimes used by ASD individuals to "count time" (Allman 2011; Allman et al. 2011).

Studies investigating time perception also suggest timing abnormalities in ASD (Falter and Noreika 2011; Martin et al. 2010). For example, ASD individuals showed deficits in the reproduction of visual and auditory temporal durations (Szelag et al. 2004; Maister and Plaisted-Grant 2011). Brenner et al. (2015), using a time reproduction task, found an interaction between clinical condition and age, with respect to reproduction accuracy, with the ASD related deficit being greater in younger children. In another study, children with ASD demonstrated less sensitivity to variability in durations under 1 s than did typically developing (TD) children; in both temporal bisection and generalization tasks (Brodeur et al. 2014).

In addition, the brain regions that are important for temporal processing, such as the frontal cortex, hippocampus, basal ganglia, and cerebellum (Meck 2005), have been related to ASD (Stanfield et al. 2008).

Despite some advances in our knowledge about temporal cognition in individuals with ASD, many challenges

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still remain. There are, for instance, no studies investigating the time-based event expectancies in ASD individuals. Time-based expectancies are a highly important aspect of human temporal cognition, which allow us to anticipate an event based on the duration of an interval (Thomaschke and Haering 2014; Kunchulia and Thomaschke 2016). Time-based expectancies are essential in many types of interaction with the environment, including verbal communication (Thomaschke and Haering 2014; Thomaschke et al. 2016). For instance, our conversation is governed by expectations of timely responding (Brosy et al. 2016), and the duration of inter-turn gaps predicts the valence of the next utterance (Roberts et al. 2011). Interestingly, ASD individuals also show an inability to sustain conversations (Milne and Griffiths 2007).

Here, we investigated the time-based event expectancies in children with Autism spectrum disorder using a binary choice response task, mimicking a basic computer game (see Thomaschke et al. 2015; Kunchulia and Thomaschke 2016, for a detailed overview of related research on non-autistic individuals). This paradigm has been successfully employed to test time-based event expectancies of young and older adults (Thomaschke et al. 2015; Kunchulia et al. 2015), in school-age children (Kunchulia et al. 2016), and under the influence of alcohol (Kunchulia and Thomaschke 2016). In this paradigm, two events and two preparatory intervals—foreperiods—each appear equally often overall; however, one of the events is paired with the short preparatory interval in 80% of it occurrence, and the other with the long preparatory interval in 80% of it occurrence. During the formation of time-based event expectation participants implicitly learn association between a particular event and a certain time interval that leads to faster responses to frequent foreperiod–target combinations, relative to infrequent ones (Thomaschke et al. 2015). However, several previous studies suggest impairments of implicit learning in ASD also in the non-temporal domain (Mostofsky et al. 2000; Gastgeb et al. 2009; Klinger and Dawson 2001; Klinger et al. 2007; Schipul and Adam 2016).

Since ASD individuals are impaired in both, time perception and implicit learning, we hypothesized that, in children with ASD, time-based event expectancies would also be impaired. Specifically, we hypothesized that the behavioral benefit of valid predictions over invalid ones would be reduced in ASD individuals.

Methods

Participants

Twenty-six children, between 6 and 11 years of age, participated in the study. 16 children (12 boys) were diagnosed with Autism spectrum disorder (ASD), and 10 (8 boys) were typically developing (TD) children. ASD Diagnosis was conducted by experienced clinicians based on the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000), and the Childhood Autism Rating Scale (CARS; Schopler et al. 1980). According to DSM-V criteria (American Psychiatric Association 2006), ASD children had severity level 1 or level 2. None of the children with ASD had any diagnosed co-morbid neurological/psychiatric disorders. Six children with ASD had signs of intellectual disability as tested with a non-verbal IQ test (Brown et al. 2010, Test of Nonverbal Intelligence (TONI-4)), and were not able to complete the behavioral task. One female with ASD was excluded from the analysis as she responded by pressing only the right mouse button during behavioral task. The remaining group of children with ASD comprised eight male and one female (mean age = 8.15 ± 1.7 years, age range 6–11; non-verbal IQ = 85.2 ± 14.1, range 71–112). None of the TD children (mean age = 8.9 ± 1.95, age range 6–11, non-verbal IQ = 104.5 ± 6.47, range 97–119) had any neurological or psychiatric diagnoses. None of them had first-order relatives with ASD.

All children with ASD were beneficiaries of the Autism Center, Child Development Institute, Tbilisi. TD children were recruited from Tbilisi secondary school. The study was approved by the local Bioethics Committee of Ivane Beritashvili Center of Experimental Biomedicine, and was performed in accordance with the Declaration of Helsinki. The written informed consent was obtained from parents of all children.

Apparatus

We used E-Prime2 for running the experiment and for collecting data (Schneider et al. 2002). Data was collected on a Windows PC with LCD display (screen resolution 1280 × 800 pixels). Responses were collected using a standard optical mouse.

Procedure

The participants performed a binary choice response task, mimicking a basic computer game. The task was to chase a carrot with a donkey character, which moved repeatedly from the bottom to the top of the screen in a zigzag left-to-right course, until it could finally be caught at a fence in the upper border of the screen. The experimental session consisted of 25 carrot chases, each chase being composed of six jumping steps. When the carrot jumped to the upper-left of the donkey, participants had to press the left mouse button to make the donkey follow the carrot leftward (pressing the right mouse button moved the donkey to the right). After the mouse click, the donkey immediately jumped on the carrot. After a short (200 ms) or long (800 ms) response stimulus interval (i.e., from mouse click to next carrot movement), the carrot jumped away again. This response–stimulus interval represented the foreperiod in this task. The carrot's movement was either diagonally upwards-left, or diagonally upwards-right. For half of the participants, the short foreperiod predicted a leftward movement of the carrot and the long foreperiod predicted a rightward movement, with 80% validity. For the other half, this relation was inverted.

When the participants pressed the wrong key or pressed the key before the carrot had jumped, an error message was displayed, an aversive tone was played over the headphones, and the game was paused for 3 s (see, Kunchulia and Thomaschke 2016; Szameitat et al. 2009; Thomaschke et al. 2015).

Expectancy was measured as preparedness for an event (i.e., carrot's movement direction) at a foreperiod. This means that if participants formed time-based expectancies they would respond faster and more accurately to frequent combinations of foreperiod and direction than to infrequent combinations.

Data analyses

Response time (RT) and error rates were each analyzed with a mixed analysis of variance (ANOVA) with the between-subjects factor of group (ASD vs. TD), and the within-subjects factors of temporal foreperiod duration (short vs. long) and frequency (frequent vs. infrequent foreperiod-event combination). Error trials were excluded from the RT analysis. Since slowing of response time is typical for ASD children (see, e.g., Baisch et al. 2017) and we were interested in slow ASD typical cognition as well, we did not excluded very slow RTs from data analysis (see Fig. 1).

Results

An ANOVA on the response times (RT) showed a significant main effect for the within-subjects factors of frequency [$F(1,17) = 6.6$, $p = 0.02$, $\eta_p^2 = 0.28$] and foreperiod duration [$F(1,17) = 5.2$, $p = 0.035$, $\eta_p^2 = 0.236$]. There were significant interactions between groups and frequency [$F(1,17) = 5.8$, $p = 0.027$, $\eta_p^2 = 0.256$], and between groups and foreperiod duration [$F(1,17) = 6.6$, $p = 0.019$, $\eta_p^2 = 0.282$], as well as a three way interaction between groups, frequency, and foreperiod duration [$F(1,17) = 5.5$, $p = 0.031$, $\eta_p^2 = 0.245$].

Separate analyses of variance (ANOVA) for groups showed a significant main effect for frequency for the ASD group, $F(1,8) = 5.5$, $p = 0.046$, $\eta_p^2 = 0.41$, which was mainly due to the fact that the children with ASD responded significantly faster to frequent combinations than to infrequent combinations, whereas TD children did not, $F(1,9) = 1.1$, $p = 0.3$, $\eta_p^2 = 0.11$. This means that the ASD group formed significant time-based expectancies but for TD children time-based expectancy was not evident. Children from both groups responded faster to long than to short foreperiods [ASD group, $F(1,8) = 5.3$, $p = 0.05$, $\eta_p^2 = 0.4$; TD group, $F(1,9) = 9.7$, $p = 0.012$, $\eta_p^2 = 0.52$]. Frequency interacted marginally with foreperiod for the ASD group due to a stronger frequency effect for the long than for the short foreperiod [$F(1,8) = 4.9$, $p = 0.057$, $\eta_p^2 = 0.382$], but it did not interact for typically developing (TD) children [$F(1,9) < 0.001$, $p = 0.99$, $\eta_p^2 < 0.001$].

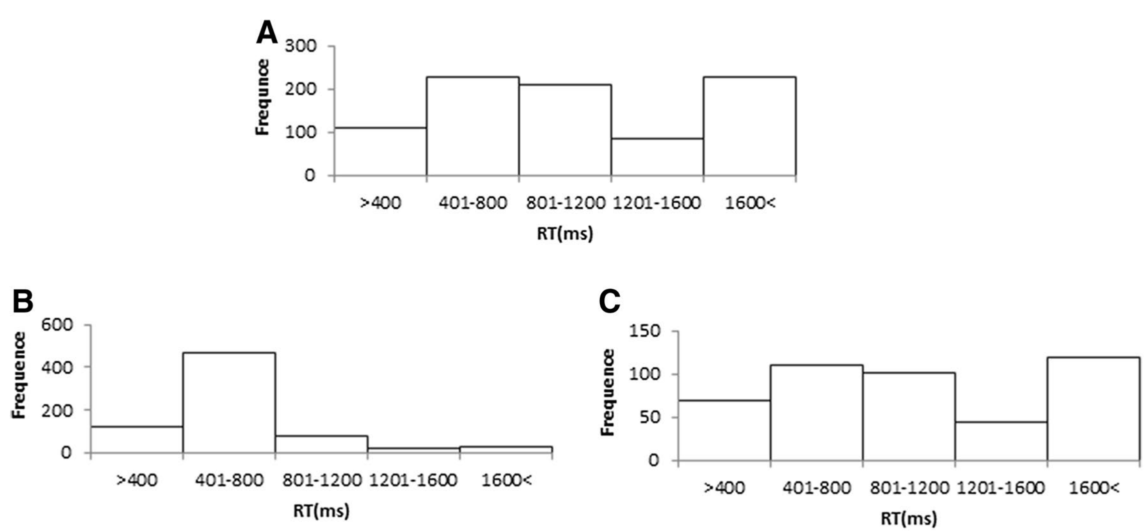

Fig. 1 Histogram of response times (RTs). **a** Histogram of RTs for both foreperiods for all participants. **b** Histogram of RTs for the long foreperiod for TD group. **c** Histogram of RTs for the long foreperiod for ASD group

Post hoc t tests revealed that a numeric advantage for frequent combinations over infrequent ones was significant for the long foreperiods, $t(8) = 2.347$, $p = 0.047$, Cohen's $d = 0.78$, for the ASD group, but not for the TD group, $t(9) = 0.6$, $p = 0.55$, Cohen's $d = 0.18$. However, for the short foreperiods, there was no significant main effect in either groups [ASD, $t(8) = 0.446$, $p = 0.667$ Cohen's $d = 0.14$; TD $t(9) = 1.23$, $p = 0.24$, Cohen's $d = 0.39$, see Fig. 2].

In an analogous ANOVA for error rates, no main effect or interaction yielded significance (see Table 1).

Table 1 A mixed analysis of variance (ANOVA) with the between-subjects factor of group (ASD vs. TD), and the within-subjects factors of foreperiod duration (short vs. long) and frequency (frequent vs. infrequent foreperiod-event combination) for error rate

	Dfs	MS	*F*	*P*	η_p^2
FP	117	3.271	0.1	0.705	0.009
Frequency	117	2.539	0.1	0.825	0.003
Group × FP	117	0.635	0.0	0.867	0.002
Group × frequency	117	15.970	0.3	0.581	0.018
FP × frequency	117	0.649	0.0	0.962	<0.001
FP × frequency × group	117	0.852	0.0	0.956	<0.001

Discussion

To our knowledge, this is the first study to investigate the time-based event expectancies in children with Autism spectrum disorder. We compared the ability to form time-based event expectancies between children with ASD and typically developing children using a binary choice response task with two different (short and long) pre-target intervals (foreperiods). In this task, participants had to indicate the left or right direction of a target stimulus, which was predicted by the duration of the foreperiod with 80% validity. Surprisingly, we found that children with ASD responded faster to frequent combinations than to infrequent combinations, suggesting that the ASD participants formed time-based event expectancies. However, this effect was not statistically significant for typically developing children. In the ASD group, the time-based event expectancy was restricted to the relatively longer pre-target interval. Our previous findings showed that time-based event expectancy was more pronounced with longer intervals in healthy young adults (e.g., Thomaschke et al. 2015). Recently, we found that the ability to form time-based event expectancies was developed in school-age TD children, but in contrast to healthy young adults, temporal predictions were closer to optimal with shorter foreperiods (Kunchulia et al. 2016). However, in the present study, we found that in children with Autism spectrum disorder, similar to healthy young adults, temporal predictions were closer to optimal with longer foreperiods, suggesting atypical neurodevelopment in ASD children.

Research investigating general timing in individuals with ASD has shown that people with ASD perform significantly worse than typical comparison participants (Droit-Volet et al. 2001; Szelag et al. 2004; Falter and Noreika 2011; Allman et al. 2011). There are also evidences of the implicit learning impairments in ASD (Mostofsky et al. 2000; Gastgeb et al. 2009; Klinger and Dawson 2001; Klinger et al. 2007; Schipul and Adam 2016). Therefore, we expected that time-based event expectancies were also impaired in ASD individuals.

However, studies of individuals with ASD have reported some superior performance in several cognitive domains. For example, high-functioning individuals with ASD were better able to detect pitch differences than IQ- and age-matched TD adults (Bonnel et al. 2003). ASD individuals showed enhanced performance in low-level, visual perceptual tasks (O'Riordan et al. 2001; Plaisted et al. 1998). Furthermore, Hagmann et al. (2016) found that children with ASD were more accurate than TD children when detecting color-marked targets. Interestingly, Travers et al. (2013), investigating implicit contextual cueing in ASD individuals, found that when only stimulus-identity cues were

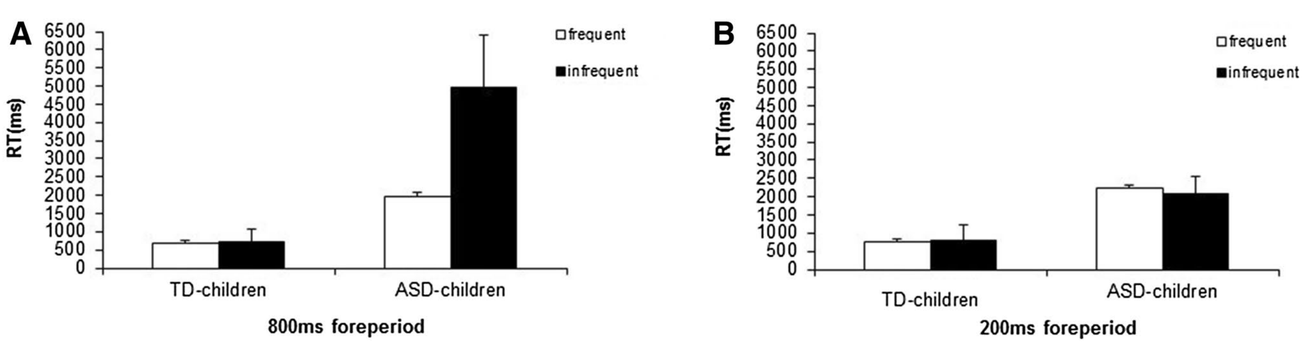

Fig. 2 Mean response times (RTs) for groups. *Error bars* represent the standard error of the mean. **a** The mean RTs for the long foreperiod. **b** The mean RTs for the short foreperiod

provided, individuals with ASD had difficulty to exploit the implicit contextual cueing; but presenting both, stimulus-identity and spatial-configuration contextual cues, lead to successful contextual cueing in persons with ASD. They suggested that ASD individual do not have a global impairment in implicit learning. Instead they may demonstrate selective implicit learning difficulties only under certain conditions but not under others (Travers et al. 2013). Our finding supports this idea. It seems that ASD individuals can use temporal cues to optimize behavior and can learn implicitly association between temporal cues and event, but have difficulties to form non-event specific temporal expectancy. In summary, we found that children with Autism spectrum disorder can form time-based event expectancies, and in contrast to typically developing children, the longer pre-target intervals are more optimal for making temporal predictions. This pattern is rather typical for healthy young adults.

These findings may suggest that ASD children have a stronger developed ability of from time-based expectancies, relative to normally developing children, while they have deficits with regards to general timing capacities. Our finding may have some practical implications for design of educational and training programs for children with ASD. For example, the usage of temporal cue to improve speech perception abilities of ASD children, as speech perception has been shown to be impaired in children with ASD (Stevenson et al. 2017). However, our study has limitations related to a sample size. In the current study, nine ASD children and ten TD children with relatively broad age ranges (6–11 years) participated. We recommend that further studies on time-based expectancy in ASD aim at testing participants with narrower age ranges or at controlling age more precisely to explore the developmental dimension of time-based expectancy in ASD.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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