Published in final edited form as:

J Autism Dev Disord. 2015 February ; 45(2): 600–611. doi:10.1007/s10803-014-2045-6.

Tracking the Sensory Environment: An ERP Study of Probability and Context Updating in ASD

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Abstract

We recorded visual event-related brain potentials (ERPs) from 32 adult male participants (16 high-functioning participants diagnosed with Autism Spectrum Disorder (ASD) and 16 control participants, ranging in age from 18–53 yrs) during a three-stimulus oddball paradigm. Target and non-target stimulus probability was varied across three probability conditions, whereas the probability of a third non-target stimulus was held constant in all conditions. P3 amplitude to target stimuli was more sensitive to probability in ASD than in TD participants, whereas P3 amplitude to non-target stimuli was less responsive to probability in ASD participants. This suggests that neural responses to changes in event probability are attention-dependant in high-functioning ASD. The implications of these findings for higher-level behaviors such as prediction and planning are discussed.

Keywords

Autism; ASD; ERP; Attention; P300; P3

Autism is a pervasive neurodevelopmental disorder that is characterized by deficits in social interaction and communication and restricted interests and/or repetitive behaviors (American Psychiatric Association 2000). Other commonly reported features associated with autism spectrum disorders (ASD) include sensory processing over- or under-sensitivity (Rogers and Ozonoff 2005), apraxia and basic motor skill deficits (Green et al. 2009; Ming et al. 2007), slowed disengagement and shifting of spatial attention (Harris et al. 1999; Townsend et al. 1999; Townsend et al. 1996), as well as executive functioning difficulties, including prediction and planning (Gomot and Wicker 2012; Hill 2004). Prediction and planning based on statistical regularities in the environment are cognitive processes that are used not only to perceive our world (identification of objects in visual noise, e.g. looking for

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pedestrians while driving in foggy weather), but also are skills used in social communication. In addition, prediction and planning heavily influence which information is attended and therefore subsequently processed. Engaging in a social interaction requires a constant, rapid updating of mental models of the given context, including assessment of the state of a social partner, prediction of the social partner's reaction to an action, and planning for an adaptive response to the social partner. These skills are rooted in the acquisition of statistical regularities developed from prior experiences with social interactions. If a person's model of social interaction is based on an inaccurate assessment of the statistical regularities inherent in social situations, awkward interactions may result. Given that persons with ASD as a group have deficits in prediction and planning, we sought to determine whether these difficulties might stem from problems with incidental learning of probabilistic relationships among events and/or with making the predictions that guide behavioral response based on these relationships.

The neural circuits implicated in the processing of probability and predictions include cortical areas related to contextual associations. These areas include the medial parietal cortex, which processes prototypical representations for typical contexts (e.g. school), structures in the medial temporal lobe that hold an episodic, physically specific representation of an immediate context, and the medial prefrontal cortex that uses this associative information to generate predictions (reviewed in Bar 2009). Associative processing has also been shown to involve other brain regions such as the striatum, the caudate nucleus, and the cerebellum (Pasupathy and Miller 2005). Our previous work has found evidence that cerebellar dysfunction may underlie some of the more prominent cognitive symptoms in ASD such as attentional deficits. Brain-behavior correlations suggest that the cerebellum affects both the speed with which attentional resources can be modulated and the associated neural responses in frontal cortex (Townsend et al. 1999; Townsend et al. 2001). These findings suggest that damage to the cerebellum results in an impaired ability to respond rapidly and accurately to environmental change that may result from an impaired ability to track and learn sequences upon which predictions about change are based, and/or an impaired ability to use predictive information.

To measure the encoding of stimulus probability, we used a classic three-stimulus 'oddball' paradigm during which event-related brain potentials (ERP) and behavioral responses were recorded (Courchesne et al. 1975). The ERP is a transient series of voltage oscillations in the brain that can be measured from the scalp in response to environmental events, using electroencephalographic recordings. ERPs are viewed as a sequence of separate but sometimes temporally overlapping components that are influenced by some combination of the physical parameters of the eliciting stimuli and psychological constructs such as memory, attention, or response processes. ERP components are traditionally defined in terms of their latency range relative to a discrete stimulus or response, distribution of voltages across the scalp, polarity, sequence, and sensitivity to experimental manipulations and instructions (Donchin et al. 1978; Luck 2005). The millisecond resolution of ERP recordings makes them particularly well-suited for answering questions related to the timing of stimulus processing. ERP waveforms may be classified as exogenous, early responses that are evoked as an obligatory sensory response (e.g. P1, N1 components), or as

endogenous, later responses that are independent of the physical properties of the stimulus and rely instead on the task being performed by the subject (e.g. P3 component).

Decades of research using the three-stimulus oddball paradigm has indicated that there are several subcomponents of the P3 response, including a P3a and a P3b response (reviewed in Polich 2007). During this paradigm, participants are asked to respond to infrequent “target” stimuli and withhold responses to frequent “standard” stimuli and infrequent “rare” stimuli. The P3a is a positive peak in the ERP occurring at frontal-central scalp locations at about 250 ms post-stimulus and is observed in response to the presentation of rare distracter stimuli that do not require a response. The P3a ERP component is associated with the orienting of attention to unexpected or significant events. The P3b is a positive peak in the ERP occurring at parietal scalp locations at about 250–500 ms and can be observed in response to the presentation of target stimuli. The P3b is associated with the engagement of attentional processes that serve to evaluate and update stimulus context. This P3b response occurs as a result of the process of comparing the current stimulus to previous stimuli in working memory. Upon encountering a target stimulus that is task-relevant, registration that a stimulus attribute change has occurred leads to an updating of stimulus context, and a subsequent response to the target stimulus. A P3b response with a slightly more central distribution may also be elicited by infrequent non-target stimuli when these stimuli are not sufficiently novel and therefore fail to elicit a P3a (Courchesne 1978; Courchesne et al. 1978). This response is also known as the “no-go” P3. The P3 ERP component is also sensitive to specific manipulations of stimulus probability and systematically increases in amplitude when target and non-target stimuli are presented less frequently (Katayama and Polich 1996; Squires et al. 1977).

Orienting attention to novel stimuli and the prediction-based updating of stimulus context as measured by ERPs is reported to be less robust in ASD than in typical development. During the processing of auditory stimuli, reduced or absent P3a responses to novel stimuli have been reported in children and adults with ASD as compared to typically developing control participants (Ceponiene et al. 2003; Courchesne et al. 1985). Reduced auditory P3b amplitudes in response to target stimuli have also been consistently observed in ASD, even with normal task performance (Courchesne et al. 1990; Kemner et al. 1995; Lincoln et al. 1993; Oades et al. 1988). Fewer studies have been conducted in the visual modality; however, their results are generally consistent with the findings in the auditory modality of atypical responses in ASD such as delayed and smaller P3a responses (Courchesne et al. 1990; Pritchard et al. 1987; Sokhadze et al. 2009). Although the P3b response to visual-spatial stimuli has been found to be reduced and delayed under some conditions or at younger ages (Hoeksma et al. 2006; Hoeksma et al. 2004; Townsend et al. 2001; Verbaten et al. 1991), the component amplitude and latency of the visual P3b to targets presented in central vision in simple discrimination tasks is not necessarily atypical in ASD (Courchesne et al. 1990; Courchesne et al. 1985; Larson et al. 2011; Novick et al. 1979; Pritchard et al. 1987; Sokhadze et al. 2012).

As a whole, the literature indicates that persons with ASD demonstrate difficulties with prediction and planning, exhibit differences in their neural responses to unexpected attention-grabbing changes in the environment and have difficulty with memory-based

updating of stimulus context. The current study was a component of a larger project to examine the basic operations that are critical to tracking the information that is used to generate predictions about subsequent events in order to prepare neural systems for optimal and rapid response. Failure of these basic operations could result in dysfunction of a variety of cognitive and behavioral responses. Our major question in the current study was whether difficulties in prediction and planning in ASD might arise from a more basic impairment in incidental learning of probabilistic relationships and thus might be affected by attentional state. We designed this study to expand on previous studies that report graded changes in the response of the P3b ERP component with a systematic change in stimulus probabilities. We specifically investigated whether modifying target-stimulus probability would result in graded changes in ERP responses to both target and non-target stimuli in subjects with ASD. We utilized a three-stimulus oddball paradigm (target, varying probability non-target, and low constant probability non-target stimuli). This manipulation also allowed us to determine whether responsiveness to distractors would also change with changing probability of the target and non-target stimuli.

Methods

Participants

Study participants were 16 male adults with an autism spectrum disorder (ASD), including only autistic disorder or Asperger syndrome, (mean age, 32.3 ± 10 , range 18–52) and 16 male age-matched typically developing (TD) control subjects (mean age, 32.8 ± 10 , range 20–53). There was no statistical difference in age between groups ($p > 0.9$). Participants with ASD were diagnosed by a licensed clinician using DSM-IV (American Psychiatric Association 2000) criteria. Two participants had a DSM-IV diagnosis only. The remaining 14 participants also had data from the Autism Diagnostic Interview, Revised (ADI-R; Lord et al. 1994) (mean Social, 27.3 ± 9 ; Communication, 19.3 ± 3 ; RRB, 7.9 ± 3) and/or the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2001) (mean Communication, 6.4 ± 2 ; Social, 10.5 ± 3 ; RRB, 2.5 ± 3). Participants with ASD were high functioning with mean performance IQ in the normal range (Mean WASI PIQ, 103.6 ± 16 , range, 73–131).

Task

The experiment followed a modified oddball design, in which stimulus probabilities were manipulated to create different probability conditions. Participants were instructed to maintain fixation within a square-shaped region, marked by a thin white outline in the center of a computer monitor, which remained on-screen constantly throughout each block of trials. Filled orange shapes (square, triangle, and circle; each stimulus subtended a visual angle of 2.5°) were presented, one at a time, inside the fixation area. One shape (the triangle) was designated the “target,” and participants were instructed to respond to its appearance by pressing a button on a response device using the index finger of their dominant hand as quickly as possible; participants were instructed to ignore the square and circle stimuli. Three experimental conditions were created by varying the probability of the triangle (“target”) and square (“varying probability non-target”) stimuli; the probability of the circle (“constant probability non-target”) remained the same across all conditions (see Table 1).

During a single trial, one of the three shapes was presented for 100 ms, followed by an inter-stimulus interval varying randomly between 800 to 1500 ms. A single block of trials consisted of 167 trials, with stimulus order randomized, and lasted an average of 3.5 min. Each participant was run on a total of nine blocks of trials (three blocks in each probability condition), with block order randomized.

EEG

Sixty-six channels of continuous EEG were recorded using the ActiveTwo data acquisition system (Biosemi, Inc, Amsterdam, Netherlands). This system provides “active” EEG amplification at the scalp that substantially minimizes movement artifacts. The amplifier gain on this system is fixed allowing ample input range (−264 to 264 mV) on a wide dynamic range (110 dB) Delta-Sigma (Σ) 24-bit AD converter. Sixty-four channel scalp data was recorded using electrodes mounted in a stretchy cap according to the International 10–10 system. Eye movements were monitored using one electrode located below the right eye and another next to the left eye; two additional electrodes were placed on the right and left mastoids. During data acquisition, all channels were referred to the system’s internal feedback loop (CMS/DRL sensors located in the parietal region), which drives the average potential of the participant (the Common Mode voltage) as close as possible to the ADC reference voltage (the amplifier “zero”). The EEG (DC–128Hz) data was digitized at 256 Hz for the off-line analyses. DC offsets were kept below 25 at all channels.

After recording, the EEG data were imported into EEGLAB, a Matlab-based toolbox for EEG signal processing (Delorme and Makeig 2004; <http://sccn.ucsd.edu/eeglab>). The data were re-referenced to the average of the left and right mastoid tracings and high-pass filtered at 0.5 Hz using a 2-way least squares FIR filter. After this preprocessing, independent component analysis (ICA) was used to remove ocular artifacts (e.g. blinks and saccades). ICA is a blind source separation algorithm used to break down EEG data into temporally independent and spatially fixed components. Visual inspection of the resulting component activations and scalp topographies was used to determine which components were to be removed from the continuous EEG (Jung et al. 2000a; Jung et al. 2000b).

Following ICA-based correction, the continuous EEG was processed using the Event-Related Potential Software System (ERPSS; Steve Hillyard and Jon Hansen, UCSD). The continuous EEG was time-locked to events of interest, and 1-second trials (100 ms pre-stimulus and 900 ms post-stimulus) were extracted. To control for ERP effects due to unequal numbers of trials (Thomas et al. 2004), we selected a subset of trials, distributed evenly across the experiment, based on the minimum available number of trials for each stimulus type (see Table 2). Selection of trials for desampling systematically retained every n th trial in a condition (n =proportion of trials to retain). For example, to reduce the number of target trials in the “Medium Target Probability” condition from the original 150 trials to 50 trials, we retained every third target trial during the Medium Probability blocks and deleted the other two. This trial selection was performed by editing the ERPSS “binlist” file that contains the condition/stimulus assignments for every trial recorded during the experiment. Following this trial reduction, automated artifact rejection was performed to exclude trials that exhibited muscle or recording artifact or excessive noise. Trials with

incorrect behavior (e.g. failure to respond to a target, or response to a non-target) were also removed prior to averaging.

The remaining data (see Table 3) for each channel were averaged for each participant and stimulus type, and the averages were digitally low-pass filtered with a Gaussian finite impulse response function (3 dB attenuation at 25 Hz). Finally, grand averages for all participants in each group were obtained.

ERP Components

P3 mean amplitude was measured for target, varying probability non-target, and constant probability non-target stimuli in all conditions. Each individual participant's average P3 peak latency (averaged across all channels) was estimated by identifying the latency of the greatest positive deflection in the 300 to 500 ms range. In rare instances, visual inspection indicated that a particular individual's average P3 peak was later than 500 ms—in that case, the later average peak latency was recorded. A participant-specific search window was created with a range of ± 100 ms from the individual participant's average P3 peak latency. In the case of no clear peak, the major positive deflection in the search window specified was used as the peak. The mean amplitude was determined from values ± 50 ms from the peak latency.

The P3 was analyzed using grouped electrodes: anterior included F1, F3, Fz, F2, F4, AF3, AF4, AFz, FC3, FC1, C1, C3, FC4, FC2, FCz, Cz, C2, C4; posterior included CP3, CP1, P1, P3, Pz, Cpz, CP4, CP2, P2, P4, PO3, O1, Oz, POz, PO4, O2. Statistical analyses were done using BMDP (Statistical Solutions Ltd. (2009) BMDP 2009. Statistical Solutions, Cork, Ireland) Analysis of Variance with Repeated Measures (group (ASD, TD) X probability condition (10, 30, 45) for behavioral analyses and group (ASD, TD) X probability condition (10, 30, 45) X electrode location (anterior, posterior) in ERP analyses with all interactions included in the model). Where sphericity assumptions were violated, significance reported uses the Greenhouse-Geisser correction.

Results

Accuracy and Response Time

Participants responded to a specified visual target stimulus and correct responses, misses, false alarms (responses to a non-target stimulus) and response times for correct responses were scored.

There were no significant differences between ASD and TD groups in performance accuracy or speed and there were also no significant group interactions with performance by probability condition. Accuracy and response times are shown in Table 4. For both groups, correct responses were high and did not vary with changes in probability while false alarms increased ($F(2,60)=6.5$, $p < 0.016$) and response time decreased ($F(2,60)=13.5$, $p < 0.0002$) with higher target probability. When accuracy was adjusted for false alarm rate (percent correct – percent false alarms), there was a marginally significant group by probability condition interaction with a trend for reduced accuracy with increased target probability in the ASD group ($F(2,60)=2.9$, $p < 0.09$).

ERP Characteristics

ERP grand averages elicited by target stimuli in each probability condition are plotted for TD participants (Figure 1) and ASD participants (Figure 2). Both groups exhibited a P3 peak at around 393 ms with a maximal centro-parietal focus. ERP variability was similar across participant groups, and is illustrated in Figure 3. A P3 peak was also visible in response to varying probability non-targets and constant probability non-targets, although the peak latency to these stimuli was somewhat earlier (see Table 5). P3 scalp distribution at maximum peak amplitude was similar across stimulus types.

P3 to Targets (Probability 10%, 30%, 45%)

For both groups, P3 responses were largest in amplitude to low probability targets and smallest in amplitude to high probability targets ($F(2,60)=10.26$, $p < 0.0004$) and this difference was larger for ASD than TD groups (interaction of diagnostic group and probability condition, $F(2,60)=3.50$, $p < 0.05$) (see Figure 4, top panel). There were no group differences in target P3 latencies as a function of probability condition.

The P3 responses to targets were largest over posterior scalp sites for both groups ($F(2,60)=28.67$, $p < 0.0001$) (see Figure 4, bottom panel), but the difference in the anterior and posterior P3s was significantly greater in the TD group (i.e., the anterior P3 was relatively larger in the ASD group, $F(2,60)=6.52$, $p < 0.02$).

P3 to Varying Probability Non-targets (Probability 80%, 60%, 45%)

For both groups, P3 responses were largest in amplitude to low probability non-targets and smallest in amplitude to high probability non-targets ($F(2,60)=31.81$, $p < 0.0001$) (see Figure 5). In contrast to the target probability responses, this difference in the P3 to varying probability non-targets was larger for TD than ASD groups (interaction of diagnostic group and probability condition, $F(2,60)=7.25$, $p < 0.002$). There were no group differences or interactions in the P3 latencies.

P3 to Low Constant Probability Non-targets (Probability 10%)

Although the probability of this non-target was constant throughout the task, P3 responses varied with task context (changes in target/non-target probability). For both groups, P3 responses were largest in amplitude to constant probability non-targets in the high target probability condition and smallest in amplitude in the low target probability condition ($F(2,60)=10.94$, $p < 0.0003$) (see Figure 6). There were no group differences or interactions in the amplitude or latency of the P3 to constant probability non-targets.

Discussion

The current study was designed to examine the sensitivity to changes in probability between ASD and typically developing (TD) control adults and the way in which these changes are affected by attention. While ASD and TD participants exhibited similar behavioral performance and overall neural response, there were important group differences in sensitivity to probability change in attended and unattended sensory stimuli.

Both groups performed the target detection task with a high level of accuracy and with a comparable speed of response. As the probability of the target stimuli increased, participants in both groups were faster at responding to target stimuli and committed more false alarms due to the increased level of response preparation required when targets were presented more frequently.

The P3 modulations with changes in stimulus probability for both ASD and TD groups were of the expected pattern based on the previous literature (an increase in P3 target amplitude with decreasing probability of target occurrence and an increase in non-target stimulus P3 amplitude with decreases in the probability of occurrence) (Katayama and Polich 1996). The latency of the P3 component also did not differ between the two groups. This is consistent with previous literature that indicates that the P3 to visual targets in central vision may be of typical amplitude and latency in autism (Courchesne et al. 1990; Courchesne et al. 1985; Novick et al. 1979; Pritchard et al. 1987).

While the pattern of P3 response was modulated in the expected manner, the contextual updating of visual stimuli with changes in stimulus probability differed significantly between the ASD and TD group as a function of attention. In the ASD group, there was a greater differentiation of target P3 response with probability change—greater increase in P3 amplitude with decreases in target probability as compared to TD subjects. This finding suggests that the ASD participants allocated more attention to the target stimuli as compared to the TD participants and that this increase in attention was greater for target stimuli of lower probability. In contrast, P3 amplitude to varying probability non-targets was less responsive to the probability change in ASD participants than in TD participants. While many studies have compared target and non-target responses to visual stimuli, to our knowledge, no other reported study has measured the effect of systematic variation in target and non-target probability on P3 response in persons with ASD. The results of the current study show that the response to task-relevant targets in a changing stimulus context is more graded in the ASD group than in TD participants suggesting a greater sensitivity for the tracking of changes in environmental events.

This amplified response to probability change in attended stimuli in ASD combined with the reduced response to the non-target stimuli, suggests that tracking probability changes in ASD may not be automatic but require conscious attention. Additional evidence for this model comes from a previous study from our group in which ASD and TD participants were asked to perform a simple target detection task in which a paired association was embedded (Townsend et al. 2011). In this task, TD participants showed both behavioral and EEG evidence of learning the implicit association. ASD participants showed no behavioral evidence of implicit learning, but surprisingly showed clear EEG evidence that the association had been learned although this information was not used to predict and plan response. After, however, the participants were explicitly informed of the paired association, ASD individuals used the predictive information to improve performance as well as did controls. Together, these findings suggest that persons with ASD are sensitive to probabilistic changes in the environment, do learn implicit associations, and in the current experiment, may be more in tune with changes in the probability of stimulus occurrence than TD participants as long as the changes in sensory context are explicitly attended.

The distribution of the target P3 response in the ASD participants, while maximal over posterior scalp sites, was characterized by a distribution over the scalp that extended more frontally than in the TD group. Together with their larger response to changes in target probability, this difference in scalp distribution suggests that the ASD participants may have slightly different neural contributions to the network of brain areas used to perform this task. This shift in P3 distribution is similar to that seen in studies of typical aging—a shift that is hypothesized to reflect change in frontal lobe inhibitory function (for a review, see Dustman et al. 1996).

While we intended to solely measure P3 response to changes of target and non-target probability, the task itself may have changed with the introduction of the 45% target/45% varying non-target/10% constant non-target condition. Under this context, the increased response to target stimuli creates a condition in which subjects must withhold a response to both non-target stimuli on approximately half of the trials (55% of the total trials in those blocks) rather than for the majority of the trials. Thus, the P3 response observed for both types of non-targets in that condition likely reflect a “no-go” P3 ERP response (Courchesne 1978; Courchesne et al. 1978). During this 45/45/10% block of trials, the P3 to the varying probability non-target was larger than to those presented during the other probability conditions during which non-targets were presented more frequently than target stimuli. When the response to varying probability non-target stimuli is compared between groups for the three different probability conditions, an interaction is observed in the non-targets that is driven by the difference in response to the 45/45/10% condition. The ASD group elicited a smaller response to varying probability non-target stimuli during this condition when compared with the TD group. Because correct behavior to the non-targets in this condition required withholding a frequent response, this smaller ERP response to non-target stimuli in the ASD group suggests a difficulty with response-suppression. This pattern is also reflected in the trend toward reduced accuracy (driven by more false alarms) in the ASD group during the 45/45/10% condition. Thus, the differential response to the varying probability non-target stimuli when compared between the groups may reflect a difficulty with suppressing a pre-potent response in ASD, rather than a distinction between the groups in their encoding of non-target probabilistic information.

P3s to the constant low probability non-target stimuli were modulated based on the context of the varying probability non-targets and target stimuli despite the unchanging probability of the low probability non-target. In both groups, rather than an anterior P3 response, these stimuli elicited a P3 response that was maximal over central-parietal sites, consistent with previous findings when rare stimuli were not sufficiently novel (Courchesne 1978; Courchesne et al. 1978) or when the target-standard discrimination is easy (Comerchero and Polich 1999; Polich and Comerchero 2003). A previous study with a similar design that used an auditory target and standard with changing probability and a second standard with constant probability of 60% found the P3 to this stimulus was not modulated with probability changes in the target/standard presentation frequency (Katayama and Polich 1996). Important differences between this study and the current study (different modalities and different frequency of the constant stimuli) likely explain the differences in P3 modulation of the constant probability stimuli. In the current study, the constant low probability non-target stimuli were effectively treated as an additional non-target stimulus.

Our study results are similar to results from Johnson and Donchin (1980) in which different standard stimuli were treated as members of a single category.

In sum, these results indicate that TD and ASD participants exhibit differences in the degree of modulation of their neural response to changes in the probability of stimulus occurrence. This distinction between groups in their response to a change in probability is principally driven by the level of attention. For attended stimuli, the ASD group showed a greater differentiation of P3 response as a function of probability change, but a smaller response to changes in probability for background stimuli when compared with the TD group. This suggests that in ASD the planning and prediction based on probability changes that promote optimal behavioral response may occur only during conscious attention. This reduced ability to implicitly predict and plan can affect many behavioral domains but would particularly affect social behavior as social context is extremely dynamic and the cues are frequently implicit.

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TD Participants

Fig. 1.

Grand average ERPs (across control participants) to target trials are overlaid by condition. Traces from a subset of 43 out of 66 recorded electrodes are shown. A prestimulus baseline period (−100 ms to 0 ms) was used

ASD Participants

Fig. 2.

Grand average ERPs (across ASD participants) to target trials are overlaid by condition. Traces from a subset of 43 out of 66 recorded electrodes are shown. A prestimulus baseline period (−100 ms to 0 ms) was used

Target ERPs at Pz

Fig. 3.

Target ERP traces at electrode location Pz from every participant are overlaid (data shown were filtered at 0.5 – 25 Hz). Individual participant traces are plotted in color; the thick black trace is the grand average of all participants in that group. In this study, variability was similar between groups.

Because of the heterogeneity of Autism Spectrum Disorders, grand-averaged waveforms may conceal subtypes who respond differently within a study sample. In their guidelines for publishing EEG/ERP studies of ASD participants, Webb et al. (this issue) suggest that each participant's data be shown.

Mean P3 Amplitude to Target Stimuli

Target P3 Scalp Distribution (at 400 ms)

Fig. 4.

(*Top*) Mean P3 amplitude (and standard error) in response to target stimuli in all three probability conditions are shown for both groups of participants (collapsed across Fz, Cz, Pz, and Oz electrodes). There was a significant interaction between group and probability condition. Data were filtered at 0.5 – 25 Hz prior to measurement; (*Bottom*) Scalp distribution of the P3 elicited by all Target stimuli. While scalp distribution is similar for all three conditions within each participant group, ASD participants have a broader anterior distribution

Mean P3 Amplitude to Varying Probability Non-Targets

Fig. 5.

Mean P3 amplitude (and standard error) in response to varying probability non-target stimuli in all three probability conditions are shown for both groups of participants (collapsed across Fz, Cz, Pz, and Oz electrodes). There was a significant interaction between group and probability condition. Data were filtered at 0.5 – 25 Hz prior to measurement

Mean P3 Amplitude to Constant Probability Non-Targets

Fig. 6.

Mean P3 amplitude (and standard error) in response to constant low probability non-target stimuli in all three probability conditions are shown for both groups of participants (collapsed across Fz, Cz, Pz, and Oz electrodes). Although the probability of these non-target stimuli remain unchanged, P3 amplitude is modulated by the probabilities of the target and other (varying probability) non-target stimuli. Data were filtered at 0.5 – 25 Hz prior to measurement

Table 1

Table 1 shows stimulus probabilities in each experimental condition. Probabilities were kept constant within a single block of trials

Stimulus	Condition		
	10/80/10% Probability	30/60/10% Probability	45/45/10% Probability
Target	.10	.30	.45
Varying Prob. Non-target	.80	.60	.45
Constant Prob. Non-target	.10	.10	.10

Table 2

Table 2 shows the total original numbers of trials per subject for each stimulus-condition pair. The number of trials per subject after down-sampling are shown in parenthesis for each stimulus-condition pair

	10/80/10% Probability	30/60/10% Probability	45/45/10% Probability
Target	50 (50)	150 (50)	225 (50)
Varying Prob. Non-target	400 (225)	300 (225)	225 (225)
Constant Prob. Non-target	50 (50)	50 (50)	50 (50)

Table 3

Table 3 shows the mean number of trials (and standard deviation is in parenthesis) per group per stimulus type following desampling and artifact rejection. Because artifact rejection was performed after desampling, larger variability is due to some participants losing more data to artifact than others

	10/80/10% Probability		30/60/10% Probability		45/45/10% Probability	
	ASD	TD	ASD	TD	ASD	TD
Target	45.3 (5.9)	47.7 (2.0)	48.4 (3.0)	48.4 (2.1)	48.3 (2.6)	49.4 (1.0)
Varying Probability Non-target	214.7 (15.4)	218.4 (7.5)	215.4 (17.4)	217.3 (7.5)	208.8 (16.5)	221.1 (3.5)
Constant Probability Non-target	45.3 (7.7)	47.9 (2.2)	47 (8.5)	48.1 (2.0)	46.9 (4.3)	48.9 (1.1)

Table 4

Table 4 shows performance at each of the three target probability conditions (low, 10%, medium, 30% and high, 45%). Shown are: % Hits (Percent correct responses), % FA (Percent false alarms to a non-target), Acc. (Adjusted Accuracy, Percent Correct – Percent False Alarms), and RT (Response Time for correct responses in milliseconds). For both groups, False Alarm rate increases ($p < 0.016$) and Response Time decreases ($p < 0.0002$) as target probability increases. There are no significant group main effects or interactions, but there is a trend for a greater decrease in adjusted accuracy with increased probability in ASD compared to controls ($p < 0.09$)

	% Hits		% FA		Acc.		RT	
	TD	ASD	TD	ASD	TD	ASD	TD	ASD
10% Targets	97.4 ± 3	98.0 ± 4	0.2 ± 0	0.8 ± 1	97.2 ± 3	97.2 ± 5	416.0 ± 52	440.1 ± 57
30% Targets	97.4 ± 4	96.0 ± 8	1.2 ± 1	2.4 ± 4	96.2 ± 5	93.6 ± 9	396.0 ± 51	423.3 ± 64
45% Targets	97.9 ± 3	95.5 ± 6	2.3 ± 2	7.3 ± 14	95.6 ± 4	88.2 ± 16	385.1 ± 58	421.6 ± 84

Table 5

Table 5 shows P3 mean latency and (standard deviation) to each stimulus type

	Target	Varying Probability Non-Target	Constant Probability Non-Target
ASD	394.8 (37)	371.5 (31)	364.8 (38)
TD	393.1 (40)	371.3 (34)	368.1 (35)