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How distinct autism and schizotypal trait dimensions influence neural predictive processing: An Event-related potential study

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ABSTRACT

The Predictive Processing framework offers insights into the neural mechanisms underlying autism and schizophrenia spectra. This study employed visual and auditory oddball tasks with varying difficulty levels to test whether brain-responses to unexpected events are different within these spectra. A total of 122 participants underwent EEG recordings and completed self-reports of autistic and schizotypal traits. Results showed that increased task difficulty significantly reduced P300 amplitudes across both sensory modalities. Higher Restricted Interests and Detail Orientation autistic traits were associated with enhanced N2 amplitudes in the difficult visual task, but there were no effects in the P300 time-window. Bayesian analyses yielded moderate evidence against any reliable association between P300 amplitudes and both autistic traits and schizotypy. Early auditory N1-P2 showed no credible relationships with schizotypal traits and only weak, task–dependent associations with autistic communication difficulties. Our study contributes to the growing literature on neural variability in autism and schizophrenia, emphasizing the importance of symptom-specific research and paving the way for more targeted investigations on predictive processing mechanisms. Moreover, the divergent findings for communication versus restricted-interests traits strengthen proposals that social and non-social dimensions in autism rely on distinct neural processes.

1. Introduction

Despite growing research in schizophrenia spectrum disorder (SSD) and autism spectrum disorder (ASD), the mechanisms underlying their symptom variety remain poorly understood across the continuum of severity. The Predictive Processing Framework (PPF) has emerged as a powerful tool for explaining neural mechanisms behind these neurodevelopmental disorders (Glatt et al., 2019; Tarasi et al., 2022). PPF posits that the brain operates by forming internal models to predict incoming sensory information. Any discrepancy between model predictions and inputs generates a prediction-error, which is expected to update pre-existing priors (Friston, 2005). Thus, perception is not solely based on incoming sensory input but instead arises from an inferential process in which stimuli are conditionally interpreted in the context of pre-existing knowledge (Clark, 2013).

Event-related potentials (ERPs) — neural responses linked to specific events – can be used for investigating this predictive mechanism, especially in tasks involving unexpected stimuli (e.g., oddball) (Wacongne et al., 2011). In oddball tasks, deviant stimuli are presented among frequent/standard stimuli, leveraging the brain's tendency to form predictions. When a deviant stimulus appears, it disrupts these predictions and requires adjusting the predictive model through prediction-errors. This is thought to be reflected in enhanced ERP amplitudes, since prediction-errors are projected to high-order cortical regions (Korka et al., 2022; Wacongne et al., 2011). Specifically, changes in P300 (or P3b) serve as a neural indicator of predictive model updates, with greater amplitudes reflecting how much the stimuli deviated from initial expectations (Korka et al., 2022). Importantly, P3b-related systems operating through active predictions seem to be sensitive to both visual (Kok and de Lange, 2014) and auditory stimuli (Chennu et al., 2013).

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Following the PPF, ASD and SSD can be characterized by an imbalance in the weight given to external stimuli and predictions, resulting in alterations in perceptual inferences and P300 amplitudes (Andersen, 2022; Tarasi et al., 2022).

1.1. PPF and ASD

ASD appears to relate to a lack of priors. That is, individuals with higher autistic traits (as measured by self-reporting tools, such as the Autism-Spectrum Quotient, AQ; Baron-Cohen et al., 2001) rely less on previous information and more on immediate sensory input (Pellicano & Burr, 2012). This sensory-driven processing style can improve performance in tasks requiring attention to detail (Happé & Frith, 2006) but can lead to a fragmented perception of the world, ultimately reflecting in feelings of unpredictability and the need for fixed daily routines (Van de Cruys et al., 2014). This superior performance (Cribb et al., 2016) and preference for predictability (Goris et al., 2020) can also be observed within the neurotypical population (e.g., high vs. low autistic traits), particularly among individuals with higher scores in the AQ Attention to Detail dimension (Wagner et al., 2024).

In the clinical population, a *meta*-analysis revealed that P3b amplitudes were reduced in ASD (vs. controls), although this effect was more homogeneous in the oddball tasks and in children/adolescents subgroups (Cui et al., 2017). Additionally, visual (vs. auditory) stimuli failed to modulate the P3b, suggesting that sensory modalities, along with task and age, may play a critical role in these effects. Still, the number of studies was relatively low to achieve robust results regarding potential moderators. In a recent study including an adult sample reporting high-autistic traits, visual tasks led to the expected increase in P3b amplitudes as suggested by the PPF; reduced P3b was only reported in auditory tasks (Mazer et al., 2024).

Overall, these findings emphasize the complexity of P3 modulations in ASD and suggest that task paradigm, sensory modality, and age (children vs. adults) can influence neurophysiological differences.

1.2. PPF and SSD

SSD, especially positive symptoms (e.g., hallucinations), seem to place excessive weight on priors — which is expected to distort perception by overriding external sensory information (Sterzer et al., 2018). As a result, internal expectations will shape and alter the perception of reality (Corlett et al., 2019) both at auditory and visual domains (Partos et al., 2016; Vercammen et al., 2008); for example, these individuals are more likely to perceive patterns, such as faces or speech, even in ambiguous stimuli, a phenomenon known as apophenia (i.e., detecting meaning in randomness) (Blain et al., 2020).

P300 reduction is a high-replicable finding in the clinical expression of SSD, particularly in auditory oddball (Hamilton et al., 2024; Jeon & Polich, 2003). Visual P300 (vP300) has also shown a reduction pattern in SSD (Oribe et al., 2015), this effect is more pronounced for auditory P300 (aP300) (Mathalon et al., 2000). Individuals at high-risk for psychosis, namely at the prodromal phase, also exhibit reductions in aP300 and vP300 (Bramon et al., 2008; Hamilton et al., 2019; M. Kim et al., 2015; Oribe et al., 2020; Van Tricht et al., 2010). P300 is indeed considered a marker for genetic risk with *meta*-analytical data showing consistent aP300 amplitude reductions in unaffected relatives, though these deficits were less pronounced than those observed in individuals diagnosed with schizophrenia (Bramon et al., 2005; Earls et al., 2016). Finally, a link between reduced aP300 amplitudes and elevated schizotypal features is reported in the general population (Deng et al., 2023; Gassab et al., 2006; Jang & Kim, 2014). Nonetheless, findings in high schizotypy and vP300 are mixed: three studies observed reduced amplitudes in high schizotypy (Davidson et al., 2018; Leung et al., 2021; Li et al., 2024), while another found no differences compared to controls (Choi et al., 2014). These discrepancies may stem from methodological heterogeneity, particularly in stimulus complexity, study design (e.g., extreme group comparisons vs. correlational analyses), sensory modality, and dimensions being assessed. Notably, some associations have been found with higher scores in both negative schizotypy (Deng et al., 2023) and positive schizotypy (Jang & Kim, 2014), although one study reported no differences for this last dimension (Sumich et al., 2014).

Thus, a significant gap remains regarding the high replicability of P300 reductions in clinical populations compared to the lack of consistency observed in schizotypal traits within the general population (as measured by the Schizotypal Personality Questionnaire, SPQ, Raine, 1991).

1.3. ASD and SSD – opposite ends of a spectrum?

Following the PPF, it is suggested that those individuals with clinically meaningful SSD-related positive symptoms (e.g., paranoia, unusual perceptual experience, and magical ideation), and ASD are opposite ends of a spectrum in terms of predictive brain mechanisms (Andersen, 2022; Crespi & Badcock, 2008; Tarasi et al., 2022). Similarly, this diametrical model is described in the general population (Zhou et al., 2019).

Differences between individuals with high-levels of autistic traits and positive schizotypy can be found in tasks requiring attention. Autistic traits are characterized by a focused attention style, enabling them to concentrate and block out irrelevant stimuli (Ploog, 2010). The opposite pattern is reported in positive schizotypy, which relates to a more diffuse kind of attention (Abu-Akel et al., 2017, Abu-Akel et al., 2018). These dimensions can be measured from the AQ attention switching and attention to detail subscales (Baron-Cohen et al., 2001) — or the Restricted Interests and Detail Orientation (RIDO) in the Portuguese adaptation (Barros et al., 2022) — and the positive scores of SPQ (Raine, 1991). These dimensions can be dissociated in the non-clinical population, while communication and social dimensions of autistic and schizotypal traits tend to overlap (Nenadić et al., 2021, Baron-Cohen et al., 2001). Therefore, our proposal is that restricted interests and detail orientation in autism and positive symptoms in schizotypy are particularly relevant to unravel PPF variations within this spectrum.

Disentangling this diametrical structure of ASD and SSD in the general population may help to elucidate their etiological pathways (Zhou et al., 2019) while reducing confounding factors of clinical samples (e.g., medication, disease onset and duration, cognitive impairments among others, Duncan & Northoff, 2013). Many ASD and SSD symptoms are distributed in a normal curve, from severe clinical pathology to milder/lower traits (Baron-Cohen et al., 2001; Mason, 2015); thus, it is expected that findings from clinical groups can be replicated, at least to a milder degree, in non-clinical populations exhibiting high-autistic and schizotypal traits. If individuals in the general population share, to some extent, similar neuronal and cognitive characteristics with those clinically diagnosed with ASD and SSD, then the study of community and subclinical samples may deepen our understanding of mechanisms underlying symptoms across these disorders, along their dimensional continuum (Dinsdale et al., 2013).

To the best of our knowledge, there are no previous attempts in the literature to disentangle influences of autistic and schizotypy dimensions using auditory and visual oddball paradigms within the same sample. This study aims to investigate the neural mechanisms of autistic and schizotypal traits in the non-clinical population, as grounded on the PPF and by manipulating stimuli modality (visual vs. auditory) and comparable parameters of task difficulty (easy vs. difficult). This last parameter will allow to reduce the difference between the expected-standard stimuli and the unexpected-target stimuli is smaller, leading individuals to rely more heavily on their expectations, resulting in a smaller prediction-error and reduced P300 amplitudes.

Considering mixed findings in P300, the PPF, and the autistic-positive schizotypy axis, we hypothesize that (H1) the P300 amplitude will be generally reduced in the difficult condition compared to the easy condition; (H2) autistic traits, particularly those related to restricted interests and detail orientation, will be positively associated with P300 amplitudes in both easy and difficult conditions; (H3) schizotypal traits, specifically positive symptoms, will be negatively associated with P300 amplitudes across easy and difficult and sensory modalities.

2. Method

This protocol was publicly registered in the Open Science Framework before the data collection (https://osf.io/7t2kd) on April 23rd, 2023 (Mazer et al., 2023). A favorable appraisal was granted by the local Ethical Committee (Faculty of Psychology and Educational Sciences, University of Porto; Ref. 2022/09–06) and from the Data Protection Office (Ref. A-T15/2023). All participants provided written informed consent and received a 5€ voucher compensation. Recruitment and data collection were conducted from March 2023 to January 2024.

2.1. Participants

A community sample of 122 participants (62 female/60 male) between 18 and 60 years old ($M = 26.99 \pm 8.97$) was recruited (cf. pre-registered power analysis). All participants had fluency in Portuguese and normal or corrected-to-normal vision. Initial screening excluded participants if they reported a neurological diagnosis, substance abuse, or uncorrected motor or sensory deficits. Due to the known comorbidities and to ensure the study was more generalizable, we did not exclude self-reported psychiatric diagnoses. A total of 20 participants reported psychiatric record, namely anxiety ($n = 6$), depression ($n = 6$), attention-deficit/hyperactivity disorder ($n = 2$), psychotic depression ($n = 1$), anorexia ($n = 1$), and a combination of anxiety with other disorders ($n = 4$). Ten participants reported medication intake at the time of data collection, mostly antidepressants ($n = 8$). Finally, seven participants reported a family history of ASD, and five reported a family history of SSD.

Additional exclusion criteria were applied during data analysis. Participants were excluded from each task modality and condition if they failed to meet any of the following criteria: 1) missed standards (non-target stimuli that participants incorrectly identified as targets) $\leq$ 50 %, 2) $\geq$ 20 artifact-free trials (Cohen & Polich, 1997), 3) $\geq$ three interpolated channels within a cluster, 4) Z-scores (± 3). Details on exclusion are provided in Table S1 (Supplemental material).

2.2. Self-Reports

The Schizotypal Personality Questionnaire (SPQ; Raine, 1991) includes 74-items with a dichotomic response format (Yes/No). Higher scores indicate higher schizotypal traits. We used the Portuguese-validated version (Santos & Paixão, 2013) with the three-factorial structure: Positive schizotypy (Cronbach's $\alpha = 0.87$), Negative schizotypy ($\alpha = 0.88$), and Disorganised Features ($\alpha = 0.78$). The SPQ dimensions were all moderately correlated to each other (r-values from 0.344 and 0.485, all $ps < 0.001$, Fig. 1).

The Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001) consists of 50 items presented in a 4-point Likert scale ("definitely agree" to "definitely disagree"). Higher scores indicate higher autistic traits. The Portuguese version (Barros et al., 2022) has a three-factorial solution: (deficits in) Social skills ($\alpha = 0.86$), (difficulties in) Communication/Imagination ($\alpha = 0.55$), and Restricted interest and Detail Orientation (RIDO; $\alpha = 0.57$). Only Communication difficulties and Social Skills deficits were positively correlated ($r(120) = 0.207$, $p = 0.022$).

Across scales, the AQ RIDO correlated with the SPQ disorganized ($r(120) = 0.252$, $p = 0.005$), while the Negative schizotypy covaried with AQ deficits in Social Skills ($r(120) = 0.408$, $p < 0.001$). No other statistically significant correlations were found (all $ps > 0.092$, Fig. 1 and Table 1).

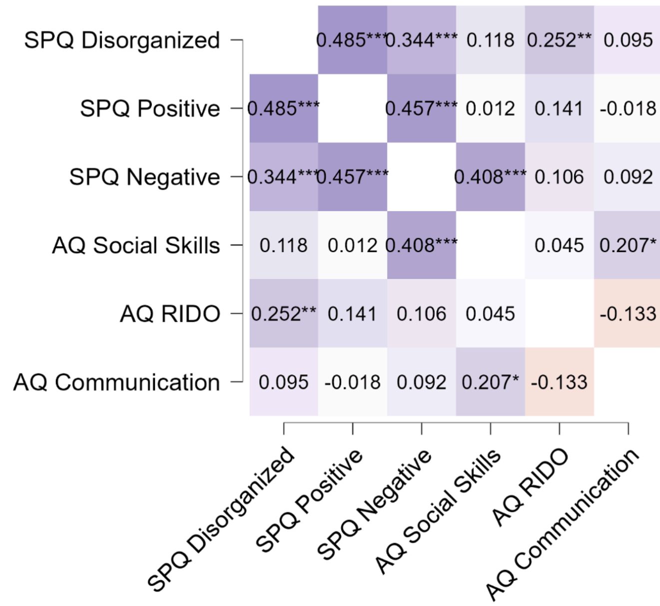

Fig. 1. Heatmap of correlations between self-report dimensions.

2.3. Experimental tasks

The tasks (Fig. 2) were programmed in E-Prime 2.0 (Version 2.0) (2002) (Psychology Software Tools, Pittsburgh, PA). Each task modality included one training block and four experimental blocks (two easy, two difficult). The training block included a sequence of 5 stimuli (4 standards, 1 target), and experimental blocks consisted of 152 stimuli (25 % probability of targets/deviants). To reduce potential confounds due to stimulus characteristics, target and standard stimuli were counterbalanced between participants (e.g., in one easy visual block, the 1° angle served as the target, and in the other block, the 7° angle did). Additionally, to prevent habituation or fatigue from biasing our difficulty manipulation, half the participants began with the easy block and half with the difficult block, and likewise, we balanced whether they started in the visual or auditory modality. Participants were informed before each block which stimulus would serve as the target. They were instructed to press a button when they saw or heard the target. Supplemental material provides more details on tasks.

2.4. EEG acquisition and processing

The EEG was recorded using a NetAmps 300 system from Electrical Geodesics Inc. (Eugene, Oregon, USA) with a 128-channel hydrocel geodesic sensor. Data processing was conducted using EEGLAB (v2021.0) for MATLAB version 9.10.0.2198249 (Version R2021a) (2021) (Delorme & Makeig, 2004). Although not originally planned, data pre-processing was performed with an automated preprocessing pipeline for ERP data (HAPPE + ER, Version 4.0, Monachino et al., 2022). Pre-processing parameters are available in Table S2.

Auditory components were calculated at: 80–200 ms (N1, Fz-cluster), 100–300 ms (P2, Fz-cluster), 350–650 ms (P300, Fz, Cz, and Pz clusters) (Luck, 2014). Visual components were extracted at: 80–200 ms (P1, Pz-cluster), 150–300 ms (N2, Pz-cluster), 350–650 ms (P300, Fz, Cz, and Pz clusters). For early components, we used the adaptive peak mean amplitude by averaging six-time points around the maximum peak (24 ms pre-peak to 24 ms post-peak), and for P300, the mean amplitude.

Table 1
Descriptive statistics of sample and self-report dimensions of the Schizotypal Personality Questionnaire (SPQ) and the Autism-Spectrum Quotient (AQ).

	Mean	*SD*	Minimum	Maximum
N (Female/Male)	122 (62/60)			
Age	26.992	8.986	18.000	60.000
SPQ Disorganized	4.344	3.185	0.000	14.000
SPQ Positive	8.287	6.073	0.000	27.000
SPQ Negative	11.492	6.611	1.000	27.000
AQ Social Skills	19.090	6.038	10.000	35.000
AQ RIDO	14.377	3.388	7.000	23.000
AQ Communication	12.246	2.873	7.000	20.000

Note. *SD* – Standard Deviation.

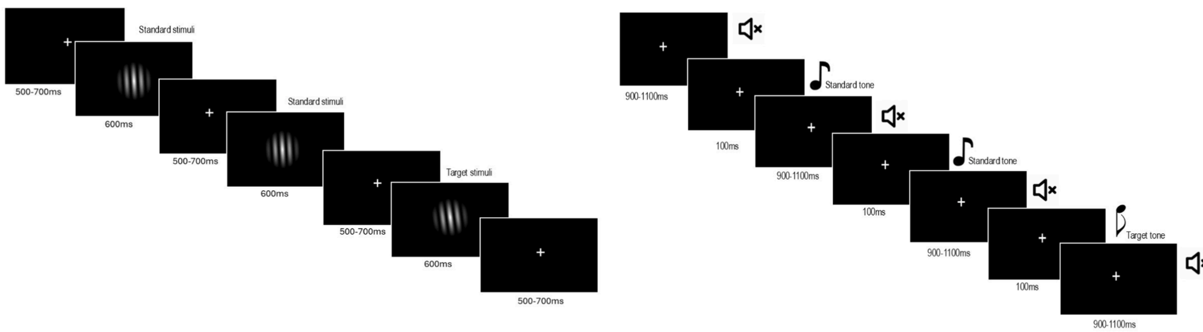

Fig. 2. Schematic illustration of the experimental paradigms. In the visual paradigm, Gabor patches were presented for 600 ms and followed by a randomized inter-stimulus interval displaying a fixation cross for 500 to 700 ms. In the auditory paradigm, 100 ms pure tones were presented and followed by a randomized inter-stimulus interval of 900 to 1100 ms.

3. Results

3.1. Behavioral measures

Behavioral data for target detection and reaction time (RT) in the easy vs. difficult conditions were analyzed with paired-sample t-tests.

RTs were significantly longer for targets in the difficult ($M_{auditory}$ = 503.00 ± 81.77, M_{visual} = 496.48 ± 55.90) vs. easy condition ($M_{auditory}$ = 460.70 ± 63.73; M_{visual} = 434.30 ± 40.92), $t_{auditory}(120) = -6.88$, $p < 0.001$, d = -0.63, $t_{visual}(120) = -17.16$, $p < 0.001$, d = -1.56.

Accuracy was also higher for the easy ($M_{auditory}$ = 85 % ± 17, M_{visual} = 94 % ± 9) vs. difficult condition ($M_{auditory}$ = 73 % ± 22; M_{visual} = 76 % ± 17), $t_{auditory}(120) = 7.95$, $p < 0.001$, $d = 0.72$, $t_{visual}(119) = 12.63$, $p < 0.001$, $d = 1.15$.

Pearson correlations examined relationships between trait dimensions and behavioral measures. RTs for difficult visual targets (r(119) = -0.210, $p = 0.021$) correlated negatively with SPQ Negative. No other significant correlations were found ($ps > 0.051$, Table S6).

3.2. Confirmatory analysis – Electrophysiological measures

To test H1, Repeated Measures 2-factor ANOVAs were conducted (difficulty with two levels: easy vs. difficult; electrode-region with three levels: Fz, Cz, and Pz clusters). The Greenhouse-Geisser correction was applied when sphericity was violated, and post hoc comparisons with Bonferroni correction explored interaction effects.

To test H2 and H3, independent Multivariate Linear Regressions explored the link between schizotypal and autistic traits with P300, for each task condition and stimuli modality. Model 1 included AQ dimensions (Social Skills, Communication, and RIDO) as predictors of P300 amplitudes across conditions (easy, difficult) and modalities (visual, auditory). Model 2 included SPQ dimensions (Positive, Negative, and Disorganised) as predictors of P300 amplitudes across conditions and modalities.

Non-significant effects from Models 1 and 2 were re-analyzed as simple Bayesian linear regressions in JASP (2024) using a default prior r scale = 0.354. Following guidelines for categorizing Bayes Factors (BF_{10}, van Doorn et al., 2021), the resulting outcomes can be quantified as follows: BF_{10} of 1 = equal support for the null and the alternative hypothesis, 1 to 3 = weak evidence in favor of the alternative hypothesis, and 3 to 10 = moderate evidence in favor of the alternative hypothesis. Conversely, to quantify evidence for the null, BF_{10} between 0.33 and 1 represents weak evidence for the null, while BF_{10} between 0.10 and 0.33 represents moderate evidence for the null.

3.2.1. aP300

The main effect of Region was significant ($F(1.22, 100.27) = 10.17$, $p < 0.001$, partial $\eta^2_{\text{partial}} = 0.110$), indicating differences in P300 amplitudes across Fz, Cz, and Pz clusters (Table 2). aP300 amplitudes were higher at Pz (M = 3.12, SD = 2.05) compared to Cz (M = 1.66 ± 1.57, $p < 0.001$) and Fz (M = 0.82 ± 1.37, $p = 0.002$). The main effect of Task was not significant ($F(1, 82) = 2.25$, $p = 0.137$, $\eta^2_{\text{partial}} = 0.027$, Table 3).

Although the Region × Task interaction did not approach significance ($F(1.37, 112.62) = 1.51$, $p = 0.227$, $\eta^2_{\text{partial}} = 0.018$), post hoc comparisons revealed that aP300 amplitudes were increased in the easy task (M = 3.34 ± 2.22), vs. the difficult task (M = 2.90 ± 2.13) at Pz ($p = 0.006$, Fig. 3).

3.2.2. vP300

There was a significant main effect of Region ($F(1.26, 119.21) = 42.48$, $p < 0.001$, $\eta^2_{\text{partial}} = 0.309$), with higher amplitudes being detected at Pz (M = 4.39 ± 2.62) vs. Cz (M = 3.22 ± 1.82) and Fz (M = 0.73 ± 3.14) ($ps < 0.001$, Table 2). The Task main effect was also significant ($F(1, 95) = 66.63$, $p < 0.001$, $\eta^2_{\text{partial}} = 0.412$), indicating that vP300 amplitude was enhanced in the easy condition (M = 3.23 ± 1.33) vs. the difficult condition (M = 2.33 ± 1.30, Fig. 4). No effects were found in the Region × Task interaction ($F(1.35, 128.03) = 1.30$, $p = 0.268$, $\eta^2_{\text{partial}} = 0.013$, Table 3), but vP300 was increased in the easy condition across all clusters ($ps < 0.024$, Table 2).

Table 2
Means and standard deviations of P300 amplitudes for targets per task and electrode cluster.

	N	Mean	*SD*	Minimum	Maximum
aP3 Easy Fz	102	0.924	5.108	−11.358	21.546
aP3 Easy Cz	108	1.824	1.691	−1.818	7.085
aP3 Easy Pz	102	3.146	2.428	−3.059	10.230
aP3 Difficult Fz	98	1.390	5.881	−8.073	23.397
aP3 Difficult Cz	105	1.651	1.792	−3.119	5.199
aP3 Difficult Pz	96	2.981	2.289	−1.102	9.942
vP3 Easy Fz	110	1.101	3.481	−9.927	10.581
vP3 Easy Cz	115	3.653	2.115	−1.858	10.698
vP3 Easy Pz	109	4.639	2.904	−1.464	12.579
vP3 Difficult Fz	109	0.532	3.480	−10.461	9.108
vP3 Difficult Cz	112	2.581	2.033	−2.311	9.736
vP3 Difficult Pz	106	3.797	2.603	−0.968	11.112

Note. SD – Standard Deviation, a – auditory, v – visual.

Table 3
Within-Subjects Effects for Region, Task, and Region x Task on Auditory and Visual P300 amplitudes.

Variable	Parameter	*F*	Hypothesis *df*	Error *df*	*p*	*%CI*
Auditory P300						
	Region	**16.17**	**2**	81	**< 0.001**	**[1.318, 2.000]**
	Task	66.63	1	82	0.137	[1.431, 2.314]
	Region*Task	2.05	2	81	0.324	[-0.307, 3.828]
Visual P300						
	Region	**24.42**	**2**	**94**	**< 0.001**	**[0.093, 1.368]**
	Task	**66.63**	**1**	**95**	**< 0.001**	**[2.063, 2.592]**
	Region*Task	2.05	2	94	0.135	[-0.283, 1.762]

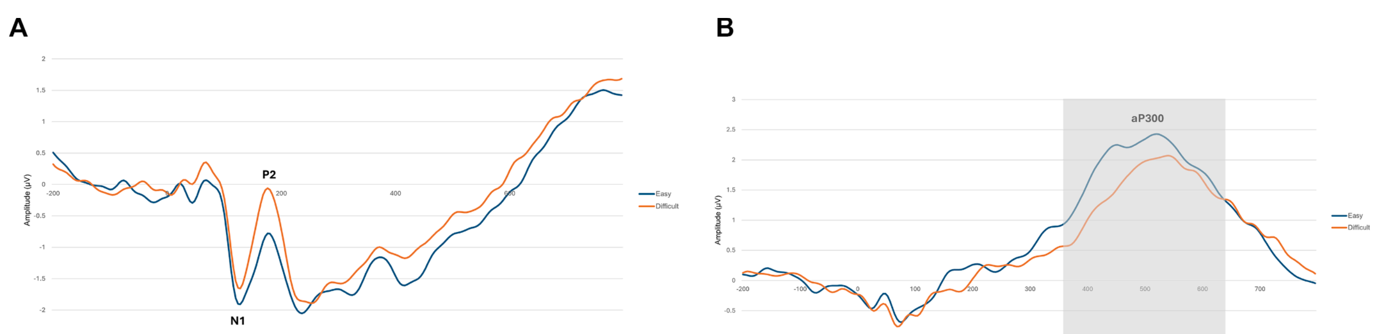

Fig. 3. Grand average ERPs in the Fz (A) and Pz (B) electrode clusters for the auditory easy and difficult target trials. The grey area represents the 350–650 ms time window corresponding to the auditory P300 component (aP300).

3.2.3. AQ and P300

Higher AQ Communication scores were associated with lower aP300 amplitudes ($AdjR^2 = 0.028$, $F(1,81) = 5.08$, $B = -0.243$, $p = 0.027$, $BF_{10} = 0.32$) in the easy oddball. However, after applying the Bonferroni correction, this result was no longer significant ($p > 0.0125$). Moreover, the inclusion Bayes factor provides weak to moderate evidence in favor of the null. No other significant results were found in the auditory modality ($ps > 0.169$, Table 4), and their Bayes factors ($BF_{10} < 0.56$) likewise indicate at least weak to moderate support for no effect (see Table 4).

3.2.4. SPQ and P300

Higher SPQ Positive scores correlated with higher aP300 amplitude in the difficult oddball ($AdjR^2 = 0.024$, $F(1,81) = 4.91$, $B = 0.099$, $p = 0.029$, $BF_{10} = 0.86$). After applying the Bonferroni correction, this result did not approach significance ($p > 0.0125$). Moreover, the inclusion Bayes factor provides moderate to weak evidence in favor of the null. No other significant result was found ($ps > 0.087$, Table 5), and their Bayes factors ($BF_{10} < 0.49$) likewise indicate at least weak to moderate support for no effect (see Table 5).

3.3. Exploratory analysis

The same analytical strategy from confirmatory analysis was used in early ERPs.

3.3.1. Auditory components (N1 and P2)

Paired samples t-tests indicated no significant differences for N1 ($t(93) = -1.64$, $p = 0.105$) and P2 across oddball conditions $t(93) = -1.63$, $p = 0.108$ (cf. Table S4).

AQ Communication scores showed nominal associations with both N1 and P2 amplitudes in the difficult auditory condition, but none survived Bonferroni correction ($ps > 0.025$). Specifically, higher scores in AQ communication were associated with lower (less negative) N1 amplitudes ($AdjR^2 = 0.030$, $F(1,90) = 3.95$, $B = 0.151$, $p = 0.039$, $BF_{10} = 1.24$, weak evidence for an effect) and larger P2 amplitudes ($AdjR^2 =$

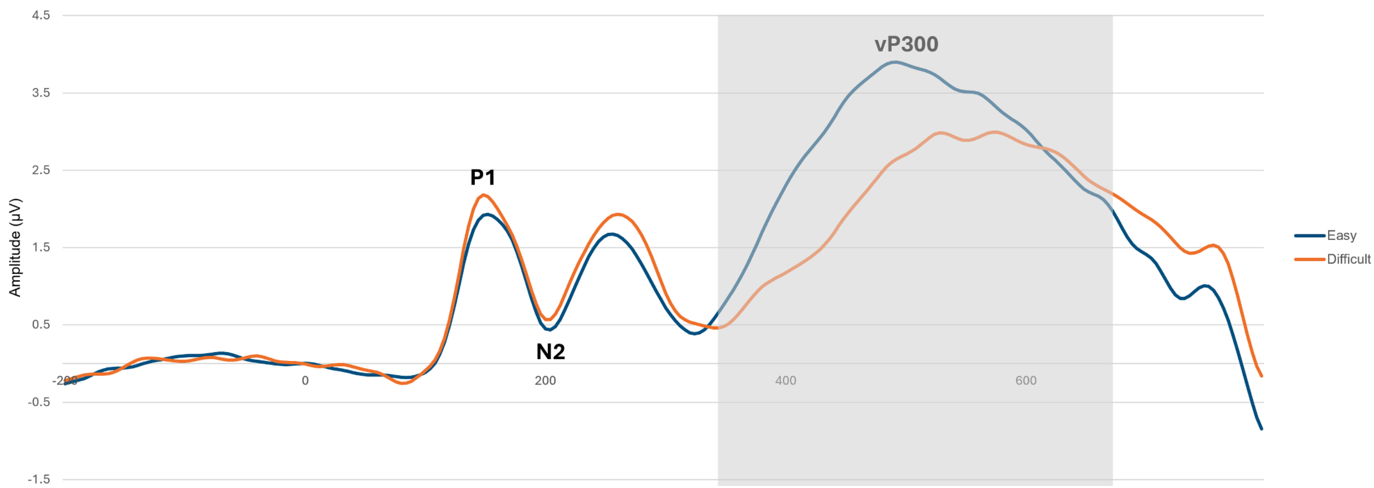

Fig. 4. Grand average ERPs in the Pz electrode cluster for the visual easy and difficult target trials. The grey area represents the 350–650 ms time window corresponding to the visual P300 component (vP300).

Table 4
Regression Analysis of Autism Spectrum Quotient (AQ) Dimensions on Auditory (aP300) and Visual (vP300) amplitudes for the Easy and Difficult (Diff) tasks.

Variable	Parameter	*B*	*SE*	*t*	*p*	*%CI*	BF_{10}
aP3 Easy Pz							
	AQ S. Skills	0.017	0.049	0.349	0.735	[-0.082, 0.115]	0.33
	AQ Com.	**−0.243**	**0.108**	**2.254**	**0.027**	**[-0.457, −0.029]**	0.32
	AQ RIDO	0.018	0.843	0.019	0.985	[-1.161, 1.197]	0.27
aP3 Diff. Pz							
	AQ S. Skills	0.032	0.048	0.667	0.498	[-0.062, 0.126]	0.29
	AQ Com.	−0.140	0.103	−1.360	0.178	[-0.344, 0.065]	0.56
	AQ RIDO	−0.031	0.104	−0.297	0.767	[-0.238, 0.176]	0.24
vP3 Easy Pz							
	AQ S. Skills	−0.037	0.074	−0.498	0.620	[-0.125, 0.051]	0.22
	AQ Com.	−0.134	0.096	−1.386	0.169	[-0.325, 0.058]	0.23
	AQ RIDO	0.051	0.080	0.629	0.531	[-0.109, 0.211]	0.20
vP3 Diff. Pz							
	AQ S. Skills	0.008	0.083	0.094	0.925	[-0.125, 0.051]	0.34
	AQ Com.	−0.124	0.090	−1.378	0.173	[-0.325, 0.058]	0.21
	AQ RIDO	0.015	0.075	0.195	0.846	[-0.109, 0.211]	0.23

Note. a – auditory, v – visual, Com. – Communication, S. Skills – Social Skills.

Table 5
Regression Analysis of Schizotypal Personality Questionnaire (SPQ) Dimensions on Auditory (aP300) and Visual (vP300) amplitudes for the Easy and Difficult (Diff) tasks.

Variable	Parameter	*B*	*SE*	*t*	*p*	*%CI*	BF_{10}
aP3 Easy Pz							
	SPQ Disor.	−0.141	0.109	−1.291	0.203	[-0.358, 0.076]	0.21
	SPQ Positive	0.04	0.056	0.723	0.472	[-0.071, 0.151]	0.49
	SPQ Negative	0.029	0.051	0.568	0.573	[-0.072, 0.130]	0.35
aP3 Diff. Pz							
	SPQ Disor.	−0.175	0.102	−1.731	0.087	[-0.377, 0.026]	0.22
	SPQ Positive	0.043	0.052	0.834	0.409	[-0.059, 0.146]	0.86
	SPQ Negative	−0.002	0.048	−0.033	0.974	[-0.094, 0.090]	0.28
vP3 Easy Pz							
	SPQ Disor.	−0.117	0.083	−1.416	0.162	[-0.307, 0.074]	0.21
	SPQ Positive	0.069	0.049	1.413	0.162	[-0.028, 0.167]	0.30
	SPQ Negative	0.027	0.046	0.615	0.541	[-0.059, 0.113]	0.44
vP3 Diff. Pz							
	SPQ Disor.	−0.09	0.087	−1.032	0.311	[-0.265, 0.084]	0.31
	SPQ Positive	**0.099**	**0.045**	**2.216**	**0.029**	**[0.010, 0.188]**	0.21
	SPQ Negative	−0.013	0.041	−0.311	0.757	[-0.094, 0.068]	0.21

Note. a – auditory, v – visual, Disor. – Disorganized.

0.028, $F(1,90) = 5.75$, $B = 0.155$, $p = 0.032$, $BF_{10} = 0.91$, weak evidence for no effect). Thus, the Bayesian re-analysis yields only weak, inconclusive support for these relationships. There were no other significant effects (*ps* > 0.050, Tables S8–S11), and their Bayes factors (BF_{10} < 0.81) indicate at least weak to moderate support for no effect (see Table S8-S11).

3.3.2. Visual components (P1 and N2)

There were no differences for P1, $t(104) = -0.785$, $p = 0.434$, and N2, $t(105) = -1.63$, $p = 0.106$, across easy and difficult tasks (Table S4).

Higher AQ RIDO scores were associated with enhanced (more negative) N2 amplitudes in the difficult visual oddball ($AdjR^2 = 0.032$, $F(1,102) = 2.09$, $B = -0.113$, $p = 0.015$, $BF_{10} = 2.97$, Fig. 5). This result remained statistically significant after Bonferroni-correction ($p < 0.025$), and the inclusion Bayes factor suggests weak to moderate support for an effect.

No reliable associations emerged for P1 or N2 or any other AQ or SPQ dimensions (all $p > 0.152$, $BF_{10} < 0.80$), indicating weak to moderate evidence in favor of the null (see Tables S12–S15). The sole exception was a weak link between AQ Social Skills and P1 amplitude in the difficult condition ($p = 0.309$, $BF_{10} = 1.55$, Table S12), suggesting a weak support for a true effect.

4. Discussion

By employing both auditory and visual oddball paradigms, we examined how schizotypal and autistic traits, conceptualized as lying at opposing ends of a spectrum under the PPF, would modulate P300 amplitudes.

We started by developing variations of the oddball task to evaluate whether we could reliably evoke ERP components while modulating task difficulty and sensory modalities. To the extent possible, we kept the physical properties of the stimuli constant across modalities, thereby enabling a comparable assessment of auditory and visual brain processing.

As expected, accuracy was higher, and reaction times smaller for the easy oddball, independently of stimuli modality. The magnitude of effects was large for auditory stimuli and very large for visual stimuli. Furthermore, vP300 and aP300 reductions were observed as a function of difficulty for deviant-target trials. As a manipulation check, this result is consistent with H1 stating that P300 amplitudes would be reduced in the difficult condition across modalities. As the difference between the expected standard stimuli and the deviant-target stimuli is smaller, individuals seem to rely more heavily on their expectations—which will translate into smaller prediction-errors and reduced P300 amplitudes as suggested by previous studies (Boetzel et al., 2024; Combs & Polich, 2006; Hagen et al., 2006; Horat et al., 2016; K. H. Kim et al., 2008; McCullag et al., 2009; Sawaki & Katayama, 2007; Sugimoto & Katayama, 2017). Interestingly, earlier auditory (N1 and P2) and visual (P1 and N2) components were not modulated by task difficulty, which makes P300 a worth exploring component to explore to test how autistic and schizotypal traits might affect prediction-error processing.

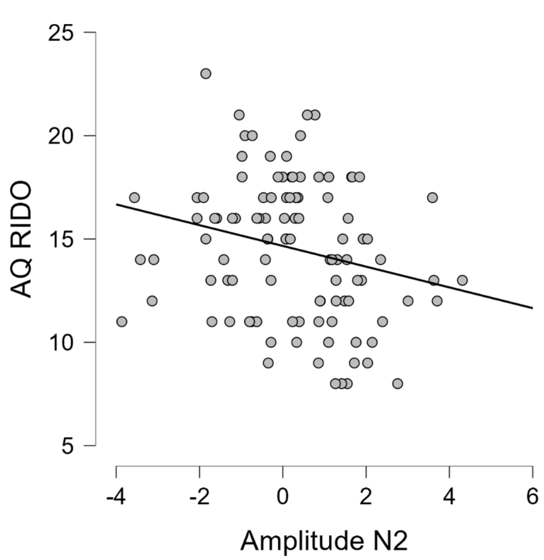

Fig. 5. Scatter plots of correlation between component N2 amplitude (microvolts; μV) to visual difficult targets and Autism Quotient (AQ) Restricted Interests and Detail Orientation (RIDO) dimension scores.

4.1. Visual and auditory P300

Our results did not support H2, as we expected that autistic traits, specifically the RIDO subscale, would correlate with P300 amplitudes. Bayesian re-analysis gave moderate evidence in favor of the null hypothesis across all oddball conditions. As such, while individuals with higher ASD traits may show heightened attention to detail, this does not necessarily translate into a direct enhancement of prediction-error signals at the P300 time-window. This lack of robust associations contrasts with the meta-analytic finding of heightened P300 in individuals with higher autistic traits (Mazer et al., 2024), particularly for visual targets. However, methodological differences across studies likely contribute to these mixed findings. Many reports of enhanced P300 in individuals with higher autistic traits relied on extreme-group designs—selecting only participants at the upper end of the AQ distribution—even when using correlational analyses (e.g., De Pascalis et al., 2020; Li et al., 2020; Meng et al., 2021; Takahashi et al., 2014; Yang et al., 2022). Clinical comparisons likewise show larger P3b amplitudes in ASD versus typically developing adults (Iwanami et al., 2014), but within their neurotypical samples, higher AQ scores actually predicted reduced P3b. Other work (Milne et al., 2013) found that the enhanced P3b in high-AQ participants was driven by responses to irrelevant stimuli rather than true target processing, which contrasts with our study, as we focused exclusively on target-evoked amplitudes.

Regarding H3, we observed no credible relationship between positive schizotypy and P300 amplitude. Bayesian re-analysis provided moderate support for the null in the visual oddballs and weak support for the null in the auditory oddballs, both indicating no true association. This contradicts previous studies reporting reduced aP300 amplitudes across positive schizotypal features in healthy (Jang & Kim, 2014) and clinical populations (Galderisi et al., 2014; Higashima et al., 2003).

Some studies failed to find the expected association between P300 modulation and positive symptoms of schizotypy. Deng and colleagues (2023) revealed that, in the control group only, aP300 was uniquely and negatively associated with SPQ negative (vs. positive) symptoms. Similarly, Sumich and colleagues (2014) found that Paranoia/Suspiciousness traits, within the positive dimension of schizotypy, were not associated with P300 in the general population. Finally, van Lutterveld and colleagues (2010) studied a group of non-psychotic individuals with auditory hallucinations and found that aP300 was increased in this group compared to individuals without hallucinations. These inconsistencies may, therefore, reflect differences in sample characteristics, tasks, and schizotypal dimensions under investigation. A distinct aspect of our study is it resorts to a continuum of severity rather than including only high scorers at the two ends of this continuum. Jang and Kim (2014) showed an amplitude reduction for the positive dimension uniquely in the high schizotypy group, but not for the low shizotypy, supporting the idea that more extreme values are needed to achieve robust results. Although we did not exclude participants with psychiatric diagnoses, the relatively low levels of positive schizotypy in our sample may have limited our power to detect significant associations.

Additionally, in our sample, the SPQ dimensions were all positively and moderately correlated, indicating a lack of clear phenotypic distinction among these schizotypal traits. This overlap may have limited our ability to detect unique associations between specific schizotypy dimensions and P300. Notably, it has been proposed that schizotypal symptoms may require more than the traditional three-factor model to capture distinct dimensions effectively (Arndt et al., 1991).

4.2. Auditory components (N1 and P2)

In the auditory domain, higher scores in the AQ (difficulties in) Communication yielded inconclusive results regarding the N1-P2 complex.

For the N1 component, evidence was weak for both the null and alternative hypotheses, suggesting ambiguity in the association between communication difficulties and N1 amplitude. Notably, task difficulty appeared to influence the strength of evidence: although both the easy and difficult oddball tasks showed a trend toward reduced N1 amplitudes with higher AQ Communication scores, Bayesian analysis provided weak evidence for the absence of an effect in the easy task (BF_{10} = 0.81) and weak evidence for the presence of an effect in the difficult task (BF_{10} = 1.24). For the P2 component, there was moderate evidence supporting the absence of an association in the easy task (BF_{10} = 0.25), but only weak evidence (BF_{10} = 0.91) in the difficult oddball. These findings indicate that the relationship between autistic traits and auditory processing, particularly at early cortical stages, may be sensitive to task characteristics such as cognitive load or attentional demands. This aligns with previous literature reporting auditory processing abnormalities in individuals with clinical ASD, especially in younger populations (Jeste & Nelson, 2009), as well as across the broader autism spectrum in neurotypical individuals (Mazer et al., 2024). Additional data, possibly including measures of task engagement or cognitive control, may be necessary to disentangle these effects more conclusively.

4.3. Visual components (P1 and N2)

A significant Bonferroni-corrected correlation between AQ RIDO scores and the N2 component was reported in the difficult condition, with the Bayesian analysis also revealing a weak to moderate support for an effect. Following PPF's proposals, individuals with higher autistic traits seem to rely to a lower extent on previous information (i.e., priors), and more on immediate sensory inputs (Pellicano & Burr, 2012). This sensory-driven processing style would result in higher processing errors, which will represent enhanced ERP amplitudes to unexpected stimuli. Thus, this outcome partially supports our H2, though we initially anticipated that this effect would manifest in the P300. It also suggests that specific autistic characteristics, such as attention to detail, may affect earlier stages of perceptual processing in tasks requiring detailed visual sensory discrimination, particularly in more challenging conditions.

Remarkably, the visual N2 observed in our study aligns closely in timing (150–300 ms) and spatial distribution (posterior) with the visual MMN waveform, which is also thought to index prediction errors in visual tasks (Pazo-Alvarez et al., 2003; Wacongne et al., 2011). The PPF states that MMN, like P300, represents prediction-errors that signal the mismatches between expected and incoming sensory information (Wacongne et al., 2011). Although our analysis focused solely on the N2 component for target-deviant stimuli, the evidence towards higher amplitudes in this component as a function of individual differences in restricted interests and attention to details outlines that components within this timeframe warrant further investigation, particularly in visual tasks and difficult conditions.

Interestingly, the RIDO dimension did not show significant correlations with other autism-related dimensions, such as Social Skills or Communication. This strengthens the proposal on the existence of distinct social and non-social dimensions in ASD (Happé & Ronald, 2008; Palmer et al., 2014). Superior performance in visual tasks specifically relates to a heightened detail-focused attentional style in autism, as measured by RIDO, rather than in combination with other social autistic dimensions (Wagner et al., 2024). Traits associated with other deficits (e.g., social attention, associative learning, or top-down control of attention) do not seem to impact individual visual search performance (Wagner et al., 2024).

These findings highlight the importance of investigating these dimensions independently to better understand their unique contributions to perceptual processing and prediction-error mechanisms in ASD.

4.4. Limitations

Some limitations in our study should be taken into consideration. Our analysis was limited to ERP components elicited by target stimuli, as we did not include an analysis of standard stimuli. This exclusion was due to our pre-registration plan, which originally focused on target stimuli alone. In addition, although we aimed to reach a broad community sample, our participants were primarily university students. This compromises the normal trait distribution, particularly in terms of cognitive and social functioning, and might have contributed to the absence of clear phenotypical dissociations in our sample. Future research should aim to encompass a broader spectrum of schizotypal and autistic traits, particularly by examining the distinct social and non-social dimensions.

Furthermore, our findings suggest unique patterns of modulation for visual and auditory processing, highlighting the need for further investigation. Future studies can incorporate multiple sensory modalities and varying task difficulties within the same sample to better understand how these factors interact with PPF across the ASD-SSD spectrum. This approach could help clarify whether the observed effects are specific to dimensions of schizotypal or autistic traits.

5. Conclusion

Our confirmatory analyses showed that P300 amplitude was reduced as task difficulty increased, but no evidence was found that autistic traits or schizotypal dimensions reliably modulate this component. Bayesian inference supported the absence of a reliable association between P300 amplitude and autistic traits across both visual and auditory modalities, and similarly, no credible association with schizotypy. While the evidence was somewhat weaker for positive schizotypy in the auditory domain, overall, our findings do not support a robust relationship between these traits and P300 activity.

Regarding exploratory analyses of earlier ERP components, we observed that autistic traits linked to restricted interests and attention to detail predicted larger N2 amplitudes in the difficult visual oddball—consistent with heightened sensory prediction-error signaling in the PPF—although we found no parallel enhancement at P300. For the N1-P2 complex, schizotypal traits showed no credible associations (moderate Bayesian support for the null), whereas autistic communication difficulties yielded only weak, task-dependent evidence for both N1 and P2 effects, indicating that further research is needed to clarify these potential associations.

Grounded on dimensional classification systems, our study contributes to explore symptom-specific neurobiological markers, independently of diagnostic categories. Moreover, the divergent findings for communication versus restricted-interests traits strengthen proposals that social and non-social dimensions in autism rely on distinct neural processes. Our research also highlights the need for research across different sensory modalities and specific phenotypes to deepen insights into neural mechanisms, with the potential to improve diagnostic and therapeutic strategies.

Declaration of generative AI in scientific writing

During the preparation of this work, the authors used ChatGPT (OpenAI, 2024) and Grammarly (2024) in order to check grammar and improve the language and readability of the text. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

CRediT authorship contribution statement

Prune Mazer: Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Rita Pasion:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Melissa Fontes:** Investigation, Formal analysis, Data curation. **Cristiana Pires:** Investigation, Formal analysis, Data curation. **Celeste Silveira:** Writing – review & editing, Supervision, Funding acquisition. **Fernando Ferreira-Santos:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bandc.2025.106329.

Data availability

The data that support the findings of this study and the task paradigms employed are openly available in Open Science Framework (OSF) at https://osf.io/5sz7p/ (https://doi.org/10.17605/OSF.IO/5SZ7P).

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