Schizophrenia Research: Cognition 28 (2022) 100235

Contents lists available at ScienceDirect

Schizophrenia Research: Cognition

journal homepage: www.elsevier.com/locate/scog

Latent inhibition, aberrant salience, and schizotypy traits in cannabis users

Christopher Dawes [a], Declan Quinn [b], Andrea Bickerdike [c], Cian O'Neill [c], Kiri T. Granger [a,d], Sarah Carneiro Pereira [e], Sue Lynn Mah [a], Mark Haselgrove [a], John L. Waddington [f], Colm O'Tuathaigh [g,*], Paula M. Moran [a]

[a] School of Psychology, University of Nottingham, NG7 2RD, UK
[b] School of Applied Psychology, University College Cork, Cork, Ireland
[c] Department of Sport, Leisure, and Childhood Studies, Munster Technological University, Bishopstown, Cork, Ireland
[d] Monument Therapeutics Ltd, Alderley Park, Congleton Road, Macclesfield SK10 4TG, UK
[e] Psychological Sciences Research Institute, Université Catholique de Louvain, Louvain-la-Neuve, Belgium
[f] School of Pharmacy and Biomolecular Sciences, Royal College of Surgeons in Ireland, St Stephen's Green, Dublin 2, Ireland
[g] Medical Education Unit, School of Medicine, University College Cork, Cork, Ireland

ARTICLE INFO

Keywords:
Cannabis
Latent inhibition
Aberrant salience
Schizotypy
Psychosis

ABSTRACT

Aberrant salience processing may underlie the link between cannabis and psychosis, as posited in individuals with schizophrenia or high schizotypy. We investigated the relative effects of cannabis use, schizotypy status, and self-reported aberrant salience experiences on salience processing, measured using a latent inhibition (LI) task (Granger et al., 2016), in a non-clinical population.

A university sample of 346 participants completed the Schizotypal Personality Questionnaire (SPQ), Aberrant Salience Inventory (ASI) the modified Cannabis Experience Questionnaire (CEQmv) and the LI task. Regression models and parallel (Bayesian and frequentist) *t*-tests or ANOVA (or non-parametric equivalents) examined differences in LI based on lifetime or current cannabis use (frequent use during previous year), as well as frequency of use. Mann-Whitney *U* tests assessed differences in SPQ and ASI scores based on current cannabis use.

Neither lifetime nor current cannabis use was associated with significant change in LI scores. Current cannabis use was associated with both higher 'Disorganised' and 'Cognitive-perceptual' SPQ dimension scores and higher total and sub-scale ASI scores. No association was observed between LI score and SPQ total and dimension scores. Higher scores on 'Senses sharpening' and the 'Heightened cognition' ASI subscales predicted decreased LI scores. These data support previous findings of no association between cannabis use and abnormality in other associative learning tasks in young non-clinical populations, and elaborate the previously demonstrated association between self-reported cannabis use, schizotypy and aberrant salience. The association between dimensions of ASI and LI performance suggests this task may have potential as an experimental measure of aberrant salience.

1. Introduction

The legalization of recreational cannabis use is associated with an increase in both consumption as well as risk of cannabis-use disorder in adolescents and adults (Cerdá et al., 2020). Early research found cannabis use to be an independent risk factor for the development of schizophrenia, allowing for psychiatric and substance use comorbidity (Andréasson et al., 1987; Zammit et al., 2002). A variety of studies have subsequently supported an association between cannabis use and the development of schizophrenia, with cannabis use in adolescents having a particular impact on cortical development in males with genotypical susceptibility to schizophrenia (French et al., 2015; Gage et al., 2017; Vaucher et al., 2018).

Schizotypy is a continuum of personality characteristics and experiences, ranging from normal dissociative states to extreme mental states related to psychosis that can extend to a clinical diagnosis of schizophrenia. Schizotypy is useful in the study of schizophrenia spectrum disorders as it can provide a framework upon which the etiological and developmental pathways to schizophrenia spectrum disorders can be tracked and dissected (Kwapil & Barrantes-Vidal, 2015; Barrantes-Vidal et al., 2015). Both schizotypy and schizophrenia comprise a similar multi-dimensional structure, with much evidence converging on the presence of three dimensions: positive, negative, and disorganised (Raine et al., 1994; Nelson et al., 2013). The cognitive deficits associated

* Corresponding author.

https://doi.org/10.1016/j.scog.2021.100235
Received 24 December 2021; Accepted 27 December 2021

with schizotypy are also well-recognised, and include difficulties in selective and sustained attention, incidental learning, and memory (Ettinger et al., 2015).

An explanation for the effect of schizotypy on cognition can be developed from the aberrant salience hypothesis of schizophrenia, which postulates that an imbalance of dopamine levels in the dopamine receptor-associated salience network is associated with inappropriate allocation of salience to all stimuli. This then leads to the emergence of psychotic symptoms, with efficiency of salience processing varying in relation to the presence of either positive or negative schizophrenia or schizotypy symptoms (Kapur, 2013; Wijayendran et al., 2018). To this end, self-reported aberrant salience experiences are associated with positive schizotypy features, with a negative association between these experiences and negative schizotypy features (Chun et al., 2020).

Aberrant salience has been described as an inability to selectively attend to certain environmental stimuli while ignoring others (Chun et al., 2020), these processes can be assessed using tasks which measure latent inhibition (LI). This is an associative learning phenomenon in which pre-exposing a stimulus without consequence delays subsequent learning to the same stimulus when it is subsequently established as a predictor of an outcome. LI can reflect the ability to selectively attend to specific stimuli over others in one's environment (Lubow & Gewirtz, 1995). Atypical LI has been shown to exist in high-schizotypy individuals, with some studies demonstrating an attenuation of LI in individuals with schizotypy, particularly those with a greater prevalence of positive features (Evans et al., 2007; Granger et al., 2012; Schmidt-Hansen et al., 2009; Wuthrich and Bates, 2001). Enhanced LI has also been observed in individuals with elevated levels of schizotypy in a task explicitly designed to test LI independently of learned irrelevance (Granger et al., 2016).

Compared to non-users, cannabis users score higher on the Aberrant Salience Inventory (ASI) a psychometric scale designed to measure aberrant salience processing (Cicero et al., 2010), with length and frequency of use positively correlated with ASI scores (Bernardini et al., 2018). O'Tuathaigh et al. (2020) reported that frequent cannabis use was associated with increased scores across selected positive and disorganised dimensions using the self-reported Schizotypal Personality Questionnaire (SPQ, Raine, 1991), as well as increased ASI scores. Despite these findings, research on cannabis use and aberrant salience is largely limited to self-report studies, with a specific knowledge gap in how differing levels of cannabis use affect performance-based measures of salience processing, such as LI, and how this might relate to levels of schizotypy in a non-clinical population.

The aim of the current study was to ascertain whether performance on a LI task was differentially affected by frequency and magnitude of cannabis use and self-reported aberrant salience experiences, as well as the extent of schizotypy. It was hypothesised that performance on the LI task would be altered in relation to frequency of cannabis use. Consistent with the literature, it was also expected that participants with higher levels of schizotypy symptoms (particularly those scoring highly on the Cognitive-Perceptual dimension and related subscales) and greater reporting of aberrant salience experiences would perform abnormally on the LI task compared to their lower scoring counterparts. Though there is conflicting evidence, depending on the task used, as to whether schizotypy improves or inhibits selective attention (Granger et al., 2016), it was hypothesised that enhanced LI would be associated with higher SPQ scores.

2. Methods

2.1. Design and participants

Participants for this study consisted of both undergraduate and postgraduate students from University College Cork (UCC) and Cork Institute of Technology (CIT). Participants were recruited from both institutions via distribution of an email containing brief details of the study and a link to both the questionnaire elements, hosted on www.typeform.com (Barcelona, Spain), and the LI task, hosted on www.pavlovia.org (Peirce et al., 2019). All study elements were completed online.

The inclusion criteria for the study were (i) individuals aged between 18 and 55 years old and (ii) from a predominantly English-speaking location. Participants were excluded if they reported a formal diagnosis with a psychiatric illness. All participants were volunteers who provided informed consent according to procedures approved by the Social Research Ethics Committee of UCC. All data was collected anonymously. No incentive was provided for participation in this study.

2.2. Questionnaire measures

Study participants completed several questionnaires to assess their schizotypy status, aberrant salience experiences and cannabis use history, in addition to a range of demographic items (age, sex, nationality, education level).

2.2.1. Schizotypy

Participants' schizotypal symptomology was measured using the Schizotypal Personality Questionnaire (SPQ; Raine, 1991). This 72-item measure of the degree to which schizotypal traits are present in individuals, is for use in healthy populations and for clinical diagnosis of schizotypal personality disorder. The SPQ identifies nine schizotypal traits: ideas of reference, odd beliefs/magical thinking, unusual perceptual experiences, suspiciousness/paranoid ideation, eccentric/odd behavior and appearance, no close friends, social anxiety, odd speech, constricted affect. These nine sub-scales load onto three separate dimensions: Cognitive-perceptual/Positive, Interpersonal, and Disorganised (Raine, 1991; Raine et al., 1994).

2.2.2. Aberrant salience

The Aberrant Salience Inventory (ASI) is a 29-item self-report measure of aberrant salience experiences that generates a five-factor model: Increased Significance, Senses Sharpening, Impending Understanding, Heightened Emotionality, and Heightened Cognition (Cicero et al., 2010). These five factors also make up a single second-order factor, allowing for the summation of scores from each factor to create the overall ASI score.

2.2.3. History of cannabis use

The Cannabis Experience Questionnaire modified version (CEQmv; Di Forti et al., 2009) was used to gauge participants' experiences, both past and present, with cannabis use. Inclusion of the CEQmv allowed for the collection of data on age at first use, lifetime cannabis consumption, current cannabis consumption (defined as frequent use of cannabis consumption during the previous 12 months), frequency of use, and use of other substances. Application of this instrument was modelled on that of O'Tuathaigh et al. (2020), whereby participants were presented with the following options: (a) lifetime use (“ever vs. never”), (b) current use (frequent use during previous year, yes/no), or (c) cannabis use frequency (5-level ordinal variable; every day, more than once a week, a few times each month, a few times each year, only once or twice ever).

2.3. Latent inhibition task

The LI task employed in this study was as described previously by Granger et al. (2016), specifically the replicated-task condition of Experiment 2 with adaptation for online delivery; a detailed description is available in the Supplemental Methods. The task had two stages: preexposure and test. During the pre-exposure stage the pre-exposed stimulus (the letter H or the letter S) was presented 20 times among filler stimuli (letters T,M, D or V), each of which was presented 15 times. At no point in the pre-exposure phase were the non-pre-exposed stimulus or the target stimulus presented on screen.

The test stage of the experiment maintained the stimulus

presentation and inter-stimulus interval times as for the pre-exposure stage. Both the pre-exposed stimulus and the non-pre-exposed stimulus were presented 20 times each, followed immediately by the target stimulus.

As in Granger et al. (2016), the target stimulus was the letter "X" and upon appearance/if participants could predict its appearance they were instructed to press the spacebar.

LI is demonstrated as slower reaction time on trials with pre-exposed stimuli compared to trials with non-pre-exposed stimuli.

2.4. Data analysis

The 20 Pre-Exposed (PE) and 20 Non-Pre-Exposed (NPE) trials were each collapsed into 4 five-trial blocks (i.e. PE Trial Block 1 was the median of PE trials 1–5). The median was taken as it is more robust against non-normality. LI was calculated by subtracting NPE scores from PE scores. Thus, larger values represent a greater magnitude of LI. Total PE, NPE, and LI variables were also calculated for analysis. Each of these three variables was non-normally distributed (according to Shapiro-Wilk tests, all $p < 0.001$) and was not normalised by either log transformations (all $p < 0.001$) or removal of outliers. As a result, Mann-Whitney *U* tests were used to examine the effects of current cannabis (Yes/No) on total LI, NPE and PE scores. One-way ANOVAs also examined the effect of cannabis use frequency ("Only once or twice" to "Every day") in the 82 current cannabis users on these three measures. Separate Linear Mixed-Effect (LME) models were used to examine the effects of current cannabis use, cannabis use frequency, SPQ scores and ASI score on the four LI, PE, and NPE trial blocks. ANOVA and LME models were used despite the non-normality of the data, as these have all been found to be robust against violations of normality (Schmider et al., 2010; Schielzeth et al., 2020). Mann-Whitney *U* tests were also used to assess differences in SPQ and ASI (also non-normally distributed, each Shapiro-Wilk test $p < 0.001$) scores based on current cannabis use.

Due to some critical null findings in the data, a parallel analysis strategy was applied to the data, in which both frequentist and Bayesian methods were used. When interpreting Bayes Factors, it should be noted that they consist of the ratio evidence for the alternative hypothesis relative to the null hypothesis (BF_{10}). For example, a BF_{10} of 5 means there is 5 times more evidence for the alternate hypothesis relative to the null. This can be converted into evidence for the null by dividing 1 by the BF_{10} (now the BF_{01}). Common cut-off criteria for BFs are as follows: values between 3 and 0.333 can be considered to indicate a lack of sensitivity to detect effects (requiring more data), a BF 3> or <0.333 represents moderate evidence for the alternate and null, respectively, 10> or <0.1 strong evidence, 30> or <0.033 very strong evidence, and 100> or <0.01 decisive evidence.

All data were collated and transferred into R Studio (R Studio Team, 2015). Graphs and figures were created in R Studio using ggplot2 (Wickham, 2016) and plotly (Sievert, 2020). All Bayesian analyses were conducted in JASP (JASP Team, 2020; https://jasp-stats.org/).

3. Results

3.1. Data cleaning and study demographics

A total of 379 participants took part in this study. Participants were removed if they failed to complete the LI task (n = 1) or simultaneously failed to respond to the cannabis use scale, SPQ and ASI questionnaire (n = 32). Outliers were not removed from the PE and NPE variables due to the PE cue distribution having a large mass of responses centering around 1.5 s; likely reflecting most participants responding to (rather than predicting) the stimulus as expected.

After data cleaning, 346 participants remained in the final sample. Participants in the final sample had a mean age of 23.9 years (SD = 7.8, range: 18 to 62 years, 62.1% female), 83.8% identified as Irish/UK nationals, 38.2% had at least an undergraduate level qualification, and 23.7% (n = 82) reported to currently using cannabis.

Table 1 presents the sociodemographic and cannabis use characteristics of the study sample. Further drug use patterns are presented in Supplementary Table 1.

Before investigating predictors of LI performance, we first assessed whether LI was exhibited in the sample overall. A parallel (frequentist and Bayesian) within-samples Wilcoxon signed-rank test indicated that response times to the PE cue (M = 1.351 s, SD = 0.297) were significantly slower ($p < 0.001$, $r_{rank\text{-}biserial} = 0.641[0.564, 0.707]$, $BF_{10} > 999$) than response times to the NPE cue (M = 1.168 s, SD = 0.373), indicating that LI was exhibited in the overall sample. This is corroborated by a significant main effect of trial block number in LME analyses of LI (see below), which suggests that levels of LI increased as the test session progressed.

We also assessed whether sex and education level (graduate education vs pre-graduate education) affected LI in the current sample. Results of this analysis are presented in the Supplementary analysis.

3.2. Cannabis use and LI performance

3.2.1. Overall task performance

3.2.1.1. Current cannabis use. Participants that do not currently use cannabis (n = 263, M = 194 ms, SD = 319 ms) did not have a significantly different total LI score ($p = 0.398$, $r_{rank\text{-}biserial} = -0.062$ [−0.202, 0.081]) than those that do currently use cannabis (n = 82, M = 145 ms, SD = 272 ms). The Bayesian adaptation suggested there was 6.58-fold more ('moderate') evidence for the null hypothesis ($BF_{10} = 0.152$). Repeating the analysis with the PE ($p = 0.099$, $BF_{10} = 0.266$) and NPE (p

Table 1
Characteristics of the sample population (n = 346).

Characteristic	n	%
Sex		
Female	215	(62.1%)
Male	131	(37.9%)
Nationality		
Irish/British	290	(83.8%)
Other Europe	26	(7.5%)
North American	14	(4.0%)
Other/not specified	16	(4.7%)
Highest level of education		
Secondary level	187	(54.0%)
Post-secondary level	25	(7.2%)
Primary degree	100	(28.9%)
Masters/Doctoral degree	32	(9.2%)
Other/not specified	2	(0.6%)
Family history of mental illness		
Yes	134	(38.7%)
No	211	(61.0%)
Not specified	1	(0.3%)
Lifetime cannabis use		
Yes	187	(54.0%)
No	158	(45.8%)
Not specified	1	(0.3%)
Current cannabis use		
Yes	82	(23.7%)
No	263	(76.2%)
Not specified	1	(0.3%)
Age at first cannabis use		
Mean age (SD)	17.6	(2.5)
Range	12–27	
Frequency of cannabis use		
Every day	11	(3.2%)
Greater than once a week	29	(8.4%)
A few times each month	39	(11.3%)
A few times each year	64	(18.5%)
Only once or twice	47	(13.6%)
Never	155	(44.8%)
Not specified	1	(0.3%)

Figures presented are number (%) unless stated otherwise.

= 0.111, BF_{10} = 0.219) variables also suggested the null was also moderately supported.

3.2.1.2. Frequency. Next, the analysis was repeated with cannabis-use frequency (five levels from "only once or twice" to "every day") as the grouping variable in current cannabis users only (n = 82). For total LI score, a parallel one-way ANOVA indicated that the main effect of cannabis use frequency was non-significant at a small size (F(4,77) = 0.305, $p = 0.874$, $\eta^2_p = 0.016$) and that there was 12.09-fold more evidence for the null model than the current model ($BF_{10} = 0.083$). This pattern of results was replicated for the NPE cue (F(4,77) = 0.651, $p = 0.628$, $\eta^2_p = 0.033$, $BF_{10} = 0.117$), although PE returned trend level evidence at a medium effect size (F(4,77) = 2.163, $p = 0.081$, $\eta^2_p = 0.101$). The BF_{10} suggested data were insensitive to detect an effect ($BF_{10} = 0.439$).

3.2.2. Cannabis use and trial block interaction

3.2.2.1. Cannabis by trial block. The analyses of LI score were repeated with trial block number (one to four) from the test stage included as an additional variable. Specifically, this assessed whether cannabis affected LI (as in the previous analyses) or whether these effects were stronger or potentially only exhibited at later trial blocks during the test sage, i.e. a cannabis * trial block interaction. LME models were used rather than ANOVAs to increase statistical power in the presence of removed data (i.e. response times >3 s). To assess whether cannabis use affected LI scores, and response times to the PE and NPE stimuli, increasingly complex nested models were compared. At each comparison, a significant $\chi 2$ test suggested the more complex model was a better fit to the data. Akaike Information Criterion (AIC) values are also reported, with lower values indicating a more parsimonious model. Due to the aim of this analysis being a model comparison, restricted maximum likelihood (REML) was not used. Significant fixed effects were determined by using the anova function from the R lme4 package and Kenward-Roger degrees of freedom approximation.

The first model contained no fixed effects (independent variables) and predicted LI from only one random effect of participant (random intercept model). This random intercept model (AIC: 729.43) also allows estimation of the proportion of variance in trial RTs explained by participant's different baseline LI scores, i.e. their personal intercepts. The analysis found that the random effect of participants explained 35.8% of the total variance, suggesting substantial individual differences in baseline LI. Next, this model was compared to a second model also containing trial block number as a fixed effect ('main effect'). This second model was a significantly better fit to the data than the null model ($\chi^2(3) = 13.021$, $p = 0.005$, AIC: 722.45) and explained an additional 0.78% of the variance (totalling 36.62%). This was supported by a significant fixed effect of trial block (F(3,1001) = 4.355, $p = 0.005$) and suggested the extent of LI differed between trial blocks. Post-hoc *t*-tests using the emmeans package (Tukey correction) indicated that Trial Block 1 was significantly different from all subsequent trial blocks (all $p < 0.042$) but all other comparisons were non-significant, suggesting that maximal levels of LI were achieved at Trial Block 2. Next, a model was proposed that investigated the potential interaction between current cannabis use (Yes/No) and trial block number (Fig. 1). This model was not a significantly better fit to the data than the previous model of trial block alone ($\chi^2(4) = 2.996$, $p = 0.558$, AIC: 727.46) and explained an additional 0.16% of variance (total 36.80%). Both the fixed effects of cannabis use ($p = 0.386$) and the cannabis * trial block interaction were non-significant ($p = 0.526$). This suggested that cannabis use did not affect LI.

The analysis was repeated in current cannabis users only (n = 82) and assessed a potential interaction between cannabis use frequency and trial block number. The model predicting LI from trial block number was not significantly better than a random intercept model ($\chi^2(3) = 0.369$, $p = 0.947$, AIC = 91.360) and presented a non-significant fixed effect of trial block number (F(3,230) = 0.123, $p = 0.947$); suggesting LI did not change across trial blocks in contrast to the previous analysis in the total sample (potentially due to reduced statistical power). Two further models compared the trial model against a model containing cannabis use frequency ($p = 0.992$) and a trial block * frequency interaction ($p = 0.222$), which were both not a significantly better fit to the data (Fig. 2). This suggested cannabis use frequency did not affect LI among current users.

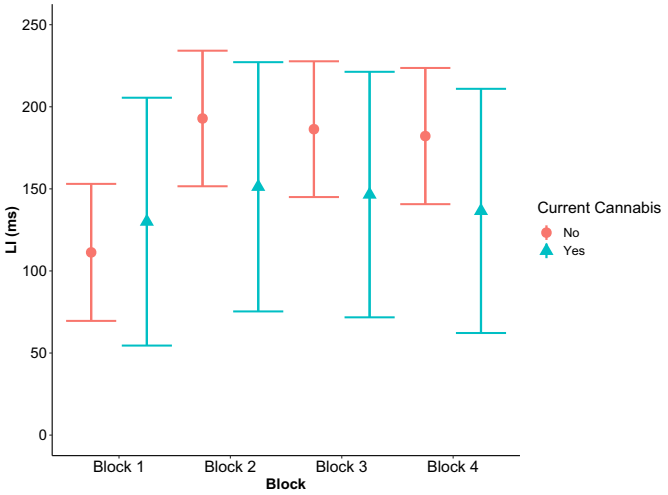

Fig. 1. Difference in mean LI score (ms) across all four trial blocks in relation to current use (n = 82) and non-use (n = 263) of cannabis. Error bars represent 95% Confidence Intervals from the respective in-text linear mixed-effects model.

3.3. Schizotypy, aberrant salience and LI task performance

The effect of both schizotypy (SPQ) and aberrant salience (ASI) were also investigated using LME models. To do so, only participants with complete data for both these scales were included (n = 328). For LI, a model containing either SPQ total ($\chi^2(1) = 1.405$, $p = 0.236$, AIC = 714.79) or a SPQ * trial block interaction ($\chi^2(4) = 2.125$, $p = 0.719$, AIC = 720) was not significantly better than the null model of trial block alone (AIC: 714.2). Further LME models also suggested the Cognitive Perceptual ($p = 0.098$), Interpersonal ($p = 0.640$), and Disorganised subscales ($p = 0.175$) presented non-significant fixed effects individually. However, a model containing ASI as a fixed effect ($\chi^2(1) = 5.055$, $p = 0.025$, AIC = 711.14) but not an ASI * trial block interaction($\chi^2(4) = 5.389$, $p = 0.250$, AIC = 716.81) was significantly better than trial block alone (AIC: 714.2). The analysis suggested that higher total ASI levels predicted lower LI across all four trial blocks (Fig. 3). To identify why this relationship may exist, ASI total score was replaced individually with each of the five ASI subscales. Of these five additional models, Heightened Cognition (F(1,325) = 5.541, $p = 0.019$) and Senses Sharpening (F(1,328) = 5.315, $p = 0.022$) presented significant fixed effects. However, when both these subscales were simultaneously added into a final model neither returned significant (both $p > 0.226$), suggesting the predictiveness of the variables was shared.

3.4. Replication analyses

Analyses were conducted to investigate whether our previous finding of an association between cannabis use and both schizotypy and aberrant salience could be replicated; these results, presented in Supplementary analysis, support earlier findings of altered SPQ and ASI scores in current cannabis users (O'Tuathaigh et al., 2020).

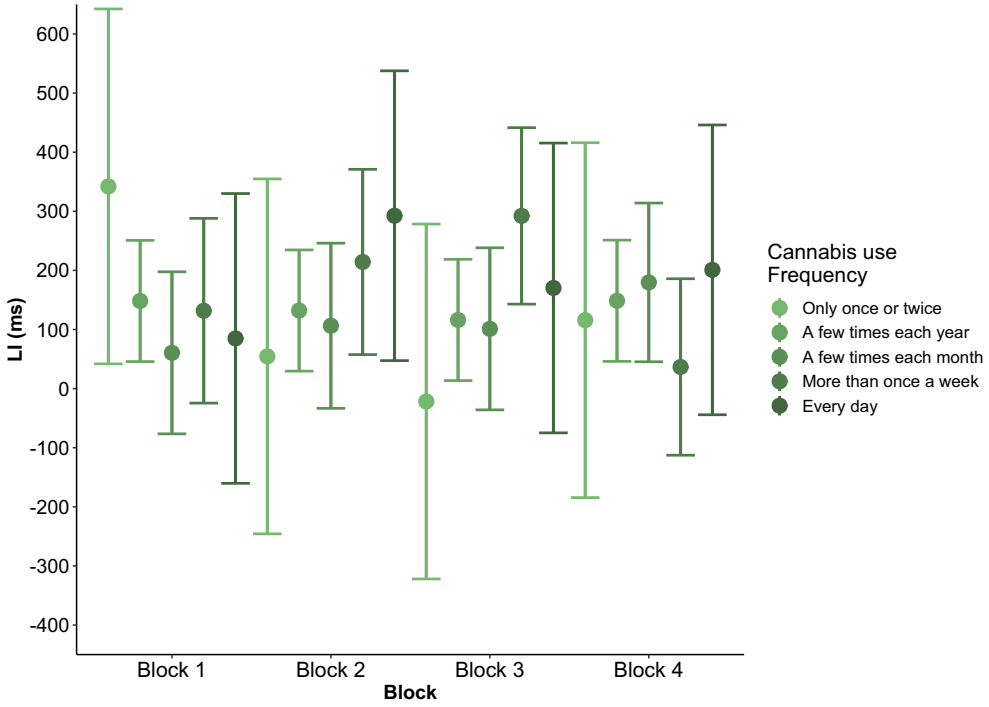

Fig. 2. Difference in mean LI score (ms) across all four trial blocks in current cannabis users (n = 82) grouped by cannabis use frequency. Error bars represent 95% Confidence Intervals from the respective in-text linear mixed-effects model.

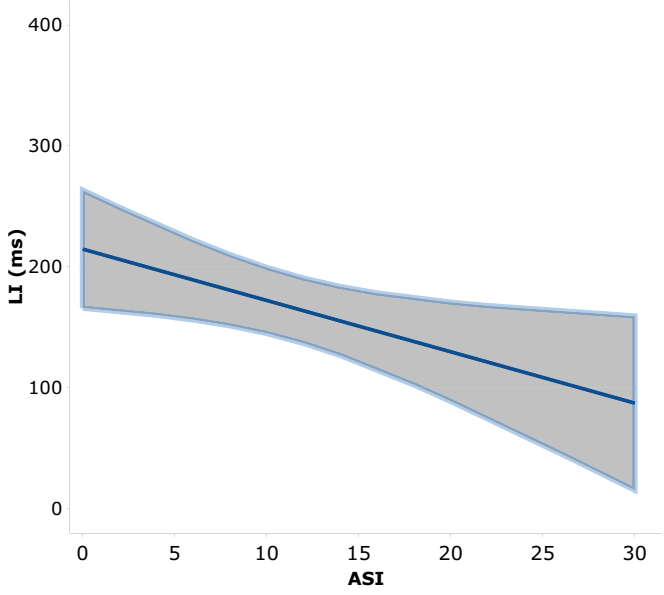

Fig. 3. LI score (ms) predicted by total ASI scores across all four trial blocks in the total sample (n = 346). Error bars represent 95% Confidence Intervals from the respective in-text linear mixed-effects model.

4. Discussion

The results of this study revealed the presence of LI in this sample, demonstrated through significantly slower reaction times to the non-pre-exposed stimulus than the pre-exposed stimulus. Performance on the LI task was not affected by self-reported lifetime or current cannabis use, nor was cannabis-use frequency associated with variation in task performance. Thus, no support was found for the hypothesised cannabis effects on the constructs under study, apart from the hypothesised (and previously shown) difference in SPQ and ASI scores between current cannabis user and non-user participants (see Supplementary analysis).

LI scores (the difference between response times to the PE and NPE stimuli) for cannabis users and non-users were not significantly different. Thus, contrary to expectations, cannabis users did not show abnormality in the LI task. These results are inconsistent with the hypothesis that cannabis users may demonstrate a schizophrenia-like profile in associative learning tasks (Skosnik et al., 2008; Nestor et al., 2008; Carey et al., 2015). In general, cognitive deficits, including associative learning difficulties, have been linked to specific parameters of cannabis use, notably earlier onset of use (Ehrenreich et al., 1999; Pope et al., 2003), longer duration of use (Solowij et al., 2002; Messinis et al., 2006), and higher frequency of use (Becker et al., 2010). Effects of long-term use of cannabis are less consistent; some have reported no evidence for effects of cannabis use (e.g. Kalant, 2004), while others reported more subtle deficits across various domains of cognition (Block et al., 2002; Bolla et al., 2002; Eldreth et al., 2004; Grant et al., 2003; Solowij et al., 2002).

The finding that self-reported cannabis use does not affect LI performance is consistent with our previous study demonstrating no relationship between history of cannabis use and Kamin blocking (KB), another associative learning task which measures the effects on current learning of prior exposure to other learning contingencies (Kamin, 1968). Both phenomena have been shown to be modifiable by pharmacological induction of hyperdopaminergic function in animals (O'Tuathaigh et al., 2003; Bay-Richter et al., 2013), and to be disrupted in patients with schizophrenia and their first-degree relatives (Martins Serra et al., 2001; Moran et al., 2003, 2008). Alongside our earlier study measuring KB performance (Dawes et al., 2021), we have now shown no difference in the magnitude of either effect in non-clinical participants reporting either lifetime or recent cannabis use. The absence of significant differences across using and non-using participants in attentional salience processing tasks has been reported previously (Kober et al., 2014; Gruber and Yurgelun-Todd, 2005; Takagi et al., 2014), confirming observations of selective cognitive dysfunction in long-term cannabis users and further suggesting that associative salience may be relatively spared in this non-clinical sample of cannabis-using individuals.

Aberrant salience has been proposed as a key mechanism in the emergence of psychotic symptoms and a putative marker of vulnerability to psychosis (Roiser et al., 2013; Winton-Brown et al., 2014; Golay et al., 2020). Specifically, a breakdown in the ability to detect and disregard irrelevant stimuli and focus on perceptually and motivationally salient stimuli is hypothesised to underlie the development of psychotic symptoms (Kapur, 2003). Both patients with schizophrenia and individuals at ultra-high-risk (UHR) for psychosis demonstrate deficits in the Salience Attribution Test, which assesses behavioural responses to task-relevant (adaptive salience) and task-irrelevant (aberrant salience) stimuli (Schmidt et al., 2017; Wilson et al., 2019). This is accompanied by a comparably high subjective experience of aberrant salience, as measured using the self-report ASI, in both UHR and first-episode psychosis patients (Poletti et al., 2021). In a complementary manner, disruption of LI has also been reported in UHR individuals (Kraus et al., 2016). However, in that study LI disruption was manifested in slower reaction times to NPE trials in UHR individuals relative to controls, while LI impairment in patients with psychosis and high schizotypy individuals typically involves changes in responsivity during PE trials (Kraus et al., 2016).

Some previous studies have failed to observe a relationship between self-reported aberrant salience processing and LI (Chun et al., 2019), SAT (Neumann et al., 2021), or other behavioural measures of salience processing (Chun et al., 2019). Our observation that ASI, and specifically the "Senses Sharpening" sub-scale, was inversely associated with LI score is congruent with our previous observation that higher scores on the 'Senses Sharpening' ASI sub-scale predicted lower KB scores only in participants who have abstained from recent cannabis (Dawes et al., 2021). It is also consistent with reports that ASI is strongly associated with AS-linked constructs such as motivation and reinforcer sensitivity (Neumann and Linscott, 2018). ASI scores are also positively correlated with everyday psychotic- and disorganisation-like experiences in undergraduate students (Chun et al., 2020). Additionally, analyses of the psychometric properties of the ASI scale have demonstrated that scores on the 'Senses Sharpening' sub-scale discriminate between psychiatric patients (including patients with psychosis) and the general population (Golay et al., 2020).

Previous studies have shown reduced LI in high schizotypal participants (Braunstein-Bercovitz et al., 2002; Lubow et al., 2001), with some having identified a relationship that is limited to specific positive, not negative, dimensions of schizotypy (Lipp et al., 1994; Evans et al., 2007; Kumari and Ettinger, 2010). However, using the within-subjects LI paradigm used by Granger et al. (2012), Chun et al. (2019) failed to show any relationship between positive or negative schizotypy and LI. Here, we also failed to observe any significant relationship between any dimension of schizotypy and LI. However, there are differences between these studies that are important to note. Schizotypy was measured using different instruments; in the present study we used SPQ, while Chun et al. (2019) used brief forms of the Wisconsin schizotypy scales and Granger et al. (2016) used the O-LIFE. These instruments are all reported to measure "schizotypy" but can reflect quite different underlying constructs, SPQ and Wisconsin reflecting a more DSM-oriented clinical derivation, while O-LIFE derives from a wider, more personality-driven approach (Mason, 2015). Tasks also differed between these studies and how LI is measured can be critically important, especially whether the task is confounded by learned irrelevance (Byrom et al., 2018; Granger et al., 2016).

Potential methodological limitations of this study include a sample limited to university attendees, and these findings may not generalise to community or clinical samples (Chun et al., 2019). On the other hand, it may be argued that these students are at an important developmental transitional period that coincides with the peak age at onset of schizophrenia. As the sample was primarily composed of people from Ireland/UK, these results may also not generalise cross-culturally, though this does open avenues for replication of this study using more culturally diverse samples. A recent study has indicated that in undergraduates that identified as black African/African-American or as second generation immigrants, the association between ASI and cannabis use is similar to that demonstrated previously in white undergraduates (Anglin et al., 2021). We did not conduct any biochemical verification of cannabis use, nor did we ask cannabis users time since last intake, thereby not excluding potential differential effects of intoxication, acute withdrawal, protracted withdrawal, or residual effects as opposed to chronic use. Finally, the survey and task elements were completed online, which meant a ceding of control over the environment in which participants carried out the LI task. Supplementary analysis of the task irrespective of cannabis use indicates a comparable pattern of performance between this web-based task and prior laboratory-based studies (see Supplementary analysis). Repetition in a laboratory-based study may nonetheless be warranted.

Cannabis-induced changes in salience processing have been observed across several laboratory and real-world measures, but this may mask the use of the term 'salience' to describe different levels of processing and a lack of clarity over what extent these constructs overlap, i.e. that salience does not represent a unitary construct across different levels of processing (Chun et al., 2019). This study showed that self-reported cannabis use did not affect aberrant salience processing as indexed by LI disruption, but does support the consensus that self-reported chronic cannabis use results in an increased propensity for psychosis proneness in users as measured using psychometric instruments. This study also showed for the first time that latent inhibition performance is associated with subjective aberrant salience experiences senses sharpening and heightened cognition. This adds to a growing body of evidence supporting the potential for variation in LI performance to represent a surrogate marker to detect the core psychological disturbance that increases the risk for conversion to a full-blown psychotic disorder (Granger et al., 2020). It has been suggested that mesolimbic dopaminergic hyperfunction drives maladaptive associative learning across the early trajectory of the illness (Kätzel et al., 2020; Millard et al., 2021), with the limited efficacy of antipsychotics, which act via D2 receptor blockade, relating to insufficient targeting to reverse aberrant salience processing and the psychological impact of years of maladaptive associate learning processes (Kätzel et al., 2020). This hypothesis and supporting data highlight the potential for early intervention that would be tailored to modification of the mechanisms of salience allocation. Further research should further investigate the relationship between self-report aberrant salience measures and LI performance in UHR and early psychosis patient populations to investigate whether it may be used to identify patients and rationalize treatment strategies.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scog.2021.100235.

Role of the funding source

None.

Declaration of competing interest

Dr. Paula Moran is a Scientific Advisory Board member and consultant for Monument Therapeutics, U.K. The remaining authors declare no competing interests.

References

Andréasson, S., Engström, A., Allebeck, P., Rydberg, U., 1987. Cannabis and schizophrenia a longitudinal study of Swedish conscripts. Lancet 330 (8574), 1483–1486.

Anglin, D.M., Tikhonov, A.A., Tayler, R., DeVylder, J., 2021. The role of aberrant salience in the association between cannabis use frequency and psychotic experiences among racial and ethnic minoritized youth. Schizophr. Res. 238, 36–43.

Barrantes-Vidal, N., Grant, P., Kwapil, T.R., 2015. The role of schizotypy in the study of the etiology of schizophrenia spectrum disorders. Schizophr. Bull. 41 (2), S408–S416.

Bay-Richter, C., O'Callaghan, M.J., Mathur, N., O'Tuathaigh, C.M., Heery, D.M., Fone, K. C., Waddington, J.L., Moran, P.M., 2013. D-amphetamine and antipsychotic drug effects on latent inhibition in mice lacking dopamine D2 receptors. Neuropsychopharmacology 38 (8), 1512–1520.
Becker, B., Wagner, D., Gouzoulis-Mayfrank, E., Spuentrup, E., Daumann, J., 2010. Altered parahippocampal functioning in cannabis users is related to the frequency of use. Psychopharmacology 209 (4), 361–374.
Bernardini, F., Gobbicchi, C., Attademo, L., Puchalski, S., Trezzi, R., Moretti, P., Tortorella, A., Loas, G., 2018. Cannabis use, psychotic like experiences and aberrant salience in a sample of Belgian students. J. Nerv. Ment. Dis. 206 (7), 493–500.
Block, R.I., O'Leary, D.S., Hichwa, R.D., Augustinack, J.C., Boles Ponto, L.L., Ghoneim, M.M., Arndt, S., Hurtig, R.R., Watkins, G.L., Hall, J.A., Nathan, P.E., Andreasen, N.C., 2002. Effects of frequent marijuana use on memory-related regional cerebral blood flow. Pharmacol. Biochem. Behav. 72 (1–2), 237–250.
Bolla, K.I., Brown, K., Eldreth, D., Tate, K., Cadet, J.L., 2002. Dose-related neurocognitive effects of marijuana use. Neurology 59 (9), 1337–1343.
Braunstein-Bercovitz, H., Rammsayer, T., Gibbons, H., Lubow, R.E., 2002. Latent inhibition deficits in high-schizotypal normals: symptom-specific or anxiety-related? Schizophr. Res. 53 (1–2), 109–121.
Byrom, N.C., Msetfi, R.M., Murphy, R.A., 2018. Human latent inhibition: problems with the stimulus exposure effect. Psychon. Bull. Rev. 25 (6), 2102–2118.
Carey, S.E., Nestor, L., Jones, J., Garavan, H., Hester, R., 2015. Impaired learning from errors in cannabis users: dorsal anterior cingulate cortex and hippocampus hypoactivity. Drug Alcohol Depend. 155, 175–182.
Cerdá, M., Mauro, C., Hamilton, A., Levy, N.S., Santaella-Tenorio, J., Hasin, D., Wall, M. M., Keyes, K.M., Martins, S.S., 2020. Association between recreational marijuana legalization in the United States and changes in marijuana use and cannabis use disorder from 2008 to 2016. JAMA Psychiatry 77 (2), 165–171.
Chun, C., Gross, G., Mielock, A., Kwapil, T., 2020. Aberrant salience predicts psychotic-like experiences in daily life: an experience sampling study. Schizophr. Res. 220, 218–224.
Cicero, D.C., Kerns, J.G., McCarthy, D.M., 2010. The aberrant salience inventory: a new measure of psychosis proneness. Psychol. Assess. 22 (3), 688–701.
Dawes, C., Bickerdike, A., O'Neill, C., Pereira, S.C., Waddington, J.L., Moran, P.M., O'Tuathaigh, C.M.P., 2021. Cannabis use, schizotypy and Kamin blocking performance. Front. Psychiatry. In Press.
Di Forti, M., Morgan, C., Dazzan, P., Pariante, C., Mondelli, V., Marques, T.R., Handley, R., Luzi, S., Russo, M., Paparelli, A., Butt, A., Stilo, S.A., Wiffen, B., Powell, J., Murray, R.M., 2009. High-potency cannabis and the risk of psychosis. Br. J. Psychiatry 195 (6), 488–491.
Ehrenreich, H., Rinn, T., Kunert, H.J., Moeller, M.R., Poser, W., Schilling, L., Gigerenzer, G., Hoehe, M.R., 1999. Specific attentional dysfunction in adults following early start of cannabis use. Psychopharmacology 142 (3), 295–301.
Eldreth, D.A., Matochik, J.A., Cadet, J.L., Bolla, K.I., 2004. Abnormal brain activity in prefrontal brain regions in abstinent marijuana users. NeuroImage 23 (3), 914–920.
Ettinger, U., Mohr, C., Gooding, D.C., Cohen, A.S., Rapp, A., Haenschel, C., Park, S., 2015. Cognition and brain function in schizotypy: a selective review. Schizophr. Bull. 41 (2), S417–S426.
Evans, L.H., Gray, N.S., Snowden, R.J., 2007. A new continuous within-participants latent inhibition task: examining associations with schizotypy dimensions, smoking status and gender. Biol. Psychol. 74 (3), 365–373.
French, L., Gray, C., Leonard, G., Perron, M., Pike, G.B., Richer, L., Séguin, J.R., Veillette, S., Evans, C.J., Artiges, E., Banaschewski, T., Bokde, A.W.L., Bromberg, U., Bruehl, R., Buchel, C., Cattrell, A., Conrod, P.J., Flor, H., Frouin, V., Paus, T., 2015. Early cannabis use, polygenic risk score for schizophrenia and brain maturation in adolescence. JAMA Psychiatry 72 (10), 1002–1011.
Gage, S.H., Jones, H.J., Burgess, S., Bowden, J., Davey Smith, G., Zammit, S., Munafò, M. R., 2017. Assessing causality in associations between cannabis use and schizophrenia risk: a two-sample Mendelian randomization study. Psychol. Med. 47 (5), 971–980.
Golay, P., Laloyaux, J., Moga, M., Della Libera, C., Larøi, F., Bonsack, C., 2020. Psychometric investigation of the french version of the aberrant salience inventory (ASI): differentiating patients with psychosis, patients with other psychiatric diagnoses and non-clinical participants. Ann. General Psychiatry 19, 58.
Granger, K.T., Prados, J., Young, A.M., 2012. Disruption of overshadowing and latent inhibition in high schizotypy individuals. Behav. Brain Res. 233 (1), 201–208.
Granger, K.T., Moran, P.M., Buckley, M.G., Haselgrove, M., 2016. Enhanced latent inhibition in high schizotypy individuals. Pers. Individ. Dif. 91, 31–39.
Grant, I., Gonzalez, R., Carey, C.L., Natarajan, L., Wolfson, T., 2003. Non-acute (residual) neurocognitive effects of cannabis use: a meta-analytic study. J. Int. Neuropsychol. Soc. 9 (5), 679–689.
Gruber, S.A., Yurgelun-Todd, D.A., 2005. Neuroimaging of marijuana smokers during inhibitory processing: a pilot investigation. Brain Res. Cogn. Brain Res. 23 (1), 107–118.
, 0.16. https://jasp-stats.org/–. (Accessed 4 May 2021).
Kalant, H., 2004. Adverse effects of cannabis on health: an update of the literature since 1996. Prog. Neuro-Psychopharmacol. Biol. Psychiatry 28 (5), 849–863.
Kamin, L.J., 1968. "Attention-like" processes in classical conditioning. In: Jone, M.R. (Ed.), Miami Symposium on the Prediction of Behavior, 1967: Aversive Stimulation. University of Miami Press, Coral Gables, Florida, pp. 9–31.
Kapur, S., 2013. Psychosis as a state of aberrant salience: a framework linking biology, phenomenology, and pharmacology in schizophrenia. Am. J. Psychiatry 160 (1), 13–23.
Kätzel, D., Wolff, A.R., Bygrave, A.M., Bannerman, D.M., 2020. Hippocampal hyperactivity as a druggable circuit-level origin of aberrant salience in schizophrenia. Front. Pharmacol. 11, 486811.
Kober, H., DeVito, E.E., DeLeone, C.M., Carroll, K.M., Potenza, M.N., 2014. Cannabis abstinence during treatment and one-year follow-up: relationship to neural activity in men. Neuropsychopharmacology 39 (10), 2288–2298.
Kraus, M., Rapisarda, A., Lam, M., Thong, J.Y.J., Lee, J., Subramaniam, M., Collinson, S. L., Chong, S.A., Keefe, R.S.E., 2016. Disrupted latent inhibition in individuals at ultra high-risk for developing psychosis. Schizophr. Res. Cogn. 6, 1–8.
Kumari, V., Ettinger, U., 2010. Latent inhibition in schizophrenia: an empirical review 2010. In: Lubow, R., Weiner, I. (Eds.), Latent Inhibition: Cognition, Neuroscience, and Applications to Schizophrenia. Cambridge University Press, New York, NY, pp. 419–447.
Kwapil, T.R., Barrantes-Vidal, N., 2015. Schizotypy: looking back and moving forward. Schizophr. Bull. 41 (2), S366–S373.
Lipp, O., Siddle, D.A.T., Arnold, S.E., 1994. Psychosis proneness in a non-clinical sample II: a multi-experimental study of "attentional malfunctioning". Pers. Individ. Dif. 17, 405–424.
Lubow, R.E., Gewirtz, J.C., 1995. Latent inhibition in humans: Data, theory, and implications for schizophrenia. Psychological Bulletin 117 (1), 87–103.
Lubow, R.E., Kaplan, O., De la Casa, G., 2001. Performance on the visual search analog of latent inhibition is modulated by an interaction between schizotypy and gender. Schizophr. Res. 52 (3), 275–287.
Martins Serra, A., Jones, S.H., Toone, B., Gray, J.A., 2001. Impaired associative learning in chronic schizophrenics and their first-degree relatives: a study of latent inhibition and the Kamin blocking effect. Schizophr. Res. 48 (2–3), 273–289.
Mason, O.J., 2015. The assessment of schizotypy and its clinical relevance. Schizophr. Bull. 41 (2), S374–S385.
Messinis, L., Kyprianidou, A., Malefaki, S., Papathanasopoulos, P., 2006. Neuropsychological deficits in long-term frequent cannabis users. Neurology 66 (5), 737–739.
Millard, S.J., Bearden, C.E., Karlsgodt, K.H., Sharpe, M.J., 2021. The prediction error hypothesis of schizophrenia: new data point to circuit specific changes in dopamine activity. Neuropsychopharmacology. https://doi.org/10.1038/s41386-021-01188-y in press.
Moran, P.M., Al-Uzri, M.M., Watson, J., Reveley, M.A., 2003. Reduced kamin blocking in non-paranoid schizophrenia: associations with schizotypy. J. Psychiatr. Res. 37 (2), 155–163.
Moran, P.M., Owen, L., Crookes, A.E., Al-Uzri, M.M., Reveley, M.A., 2008. Abnormal prediction error is associated with negative and depression symptoms in schizophrenia. Prog. Neuro-Psychopharmacol. Biol. Psychiatry 32 (1), 116–123.
Nelson, M.T., Seal, M.L., Pantelis, C., Phillips, L.J., 2013. Evidence of a dimensional relationship between schizotypy and schizophrenia: a systematic review. Neurosci. Biobehav. Rev. 37 (3), 317–327.
Nestor, L., Roberts, G., Garavan, H., Hester, R., 2008. Deficits in learning and memory: parahippocampal hyperactivity and frontocortical hypoactivity in cannabis users. NeuroImage 40 (3), 1328–1339.
Neumann, S.R., Linscott, R.J., 2018. The relationships among aberrant salience, reward motivation, and reward sensitivity. Int. J. Methods Psychiatr. Res. 27 (4), e1615.
Neumann, S.R., Glue, P., Linscott, R.J., 2021. Aberrant salience and reward processing: a comparison of measures in schizophrenia and anxiety. Psychol. Med. 51 (9), 1507–1515.
O'Tuathaigh, C.M.P., Salum, C., Young, A.M.J., Pickering, A.D., Joseph, M.H., Moran, P. M., 2003. The effect of amphetamine on Kamin blocking and overshadowing. Behav. Pharmacol. 14 (4), 315–322.
O'Tuathaigh, C.M.P., Dawes, C., Bickerdike, A., Duggan, E., O'Neill, C., Waddington, J.L., Moran, P.M., 2020. Does cannabis use predict psychometric schizotypy via aberrant salience? Schizophr. Res. 220, 194–200.
Peirce, J.W., Gray, J.R., Simpson, S., MacAskill, M.R., Höchenberger, R., Sogo, H., Kastman, E., Lindeløv, J., 2019. PsychoPy2: experiments in behavior made easy. Behav. Res. Method. https://doi.org/10.3758/s13428-018-01193-y.
Poletti, M., Pelizza, L., Azzali, S., Garlassi, S., Scazza, I., Paterlini, F., Chiri, L.R., Pupo, S., Raballo, A., 2021. Subjective experience of aberrant salience in young people at Ultra-High Risk (UHR) for psychosis: a cross-sectional study. Nord. J. Psychiatry 1–9.
Pope Jr., H.G., Gruber, A.J., Hudson, J.I., Cohane, G., Huestis, M.A., Yurgelun-Todd, D., 2003. Early-onset cannabis use and cognitive deficits: what is the nature of the association? Drug Alcohol Depend. 69 (3), 303–310.
R Studio Team, 2015. RStudio Integrated Development for R. http://www.rstudio.com/. http://www.rstudio.com/.
Raine, A., 1991. The SPQ: a scale for the assessment of schizotypal personality based on DSM-III-R criteria. Schizophr. Bull. 17 (4), 555–564.
Raine, A., Reynolds, C., Lencz, T., Scerbo, A., Triphon, N., Kim, D., 1994. Cognitive-perceptual, interpersonal, and disorganized features of schizotypal personality. Schizophr. Bull. 20 (1), 191–201.
Roiser, J.P., Howes, O.D., Chaddock, C.A., Joyce, E.M., McGuire, P., 2013. Neural and behavioral correlates of aberrant salience in individuals at risk for psychosis. Schizophr. Bull. 39 (6), 1328–1336.
Schielzeth, H., Dingemanse, N.J., Nakagawa, S., Westneat, D.F., Allegue, H., Teplitsky, C., Reale, D., Dochtermann, N.A., Garamszegi, L.Z., Araya-Ajoy, Y.G., 2020. Robustness of linear mixed-effects models to violations of distributional assumptions. Methods Ecol. Evol. 11 (9), 1141–1152.
Schmider, E., Ziegler, M., Danay, E., Beyer, L., Bühner, M., 2010. Is it really robust?: reinvestigating the robustness of ANOVA against violations of the normal distribution assumption. Methodol. Eur. J. Res. Method. Behav. Soc. Sci. 6 (4), 147–151.
Schmidt, A., Antoniades, M., Allen, P., Egerton, A., Chaddock, C.A., Borgwardt, S., Fusar-Poli, P., Roiser, J.P., Howes, O., McGuire, P., 2017. Longitudinal alterations in motivational salience processing in ultra-high-risk subjects for psychosis. Psychol. Med. 47 (2), 243–254.

Schmidt-Hansen, M., Killcross, A.S., Honey, R.C., 2009. Latent inhibition, learned irrelevance, and schizotypy: assessing their relationship. Cog. Neuropsychiatry 14 (1), 11–29.
Sievert, C., 2020. Interactive Web-based Data Visualization With R, Plotly, and Shiny. Chapman and Hall/CRC. https://doi.org/10.1201/9780429447273.
Skosnik, P.D., Edwards, C.R., O'Donnell, B.F., Steffen, A., Steinmetz, J.E., Hetrick, W.P., 2008. Cannabis use disrupts eyeblink conditioning: evidence for cannabinoid modulation of cerebellar-dependent learning. Neuropsychopharmacology 33 (6), 1432–1440.
Solowij, N., Stephens, R.S., Roffman, R.A., Babor, T., Kadden, R., Miller, M., Christiansen, K., McRee, B., Vendetti, J., Marijuana Treatment Project Research Group, 2002. Cognitive functioning of long-term heavy cannabis users seeking treatment. JAMA 287 (9), 1123–1131.
Takagi, M.J., Lubman, D.I., Cotton, S.M., Verdejo-García, A., Vilar-López, R., Yücel, M., 2014. A signal detection analysis of executive control performance among adolescent inhalant and cannabis users. Subst. Use Misuse. 49 (14), 1920–1927.
Vaucher, J., Keating, B.J., Lasserre, A.M., Gan, W., Lyall, D.M., Ward, J., Smith, D.J., Pell, J.P., Sattar, N., Paré, G., Holmes, M.V., 2018. Cannabis use and risk of schizophrenia: a mendelian randomization study. Mol. Psychiatry 23 (5), 1287–1292.
Wickham, H., 2016. ggplot2: Elegant Graphics for Data Analysis. Retrieved from. Springer-Verlag, New York. https://ggplot2.tidyverse.org.
Wijayendran, S.B., O'Neill, A., Bhattacharyya, S., 2018. The effects of cannabis use on salience attribution: a systematic review. Acta Neuropsychiatrica 30 (1), 43–57.
Wilson, R., Bossong, M.G., Appiah-Kusi, E., Petros, N., Brammer, M., Perez, J., Allen, P., McGuire, P., Bhattacharyya, S., 2019. Cannabidiol attenuates insular dysfunction during motivational salience processing in subjects at clinical high risk for psychosis. Transl. Psychiatry 9 (1), 203.
Winton-Brown, T.T., Fusar-Poli, P., Ungless, M.A., Howes, O.D., 2014. Dopaminergic basis of salience dysregulation in psychosis. Trends Neurosci. 37 (2), 85–94.
Wuthrich, V., Bates, T.C., 2001. Schizotypy and latent inhibition: non-linear linkage between psychometric and cognitive markers. Pers. Individ. Dif. 30 (5), 783–798.
Zammit, S., Allebeck, P., Andreasson, S., Lundberg, I., Lewis, G., 2002. Self-reported cannabis use as a risk factor for schizophrenia in Swedish conscripts of 1969: historical cohort study. BMJ 325 (7374), 1199–1201.