Not all stress is created equal: Acute, not ambient stress, impairs learning in high schizotypes

Abstract

Learning from feedback is essential for daily functioning, with factors that impact learning having implications for healthy and clinical populations. Reinforcement learning appears impaired across the psychosis continuum, with deficits reported in patients with psychotic disorders as well as high schizotypes from the general population. Stress can impair learning, and sensitivity to stress is present along the psychosis continuum. The aim of the present study was to understand if stress impairs reinforcement learning in those at the lower end of the psychosis continuum. We investigated both naturalistic stress in everyday life using daily hassles (Study 1: n=70; 31% male, mean age 22.67) and acute psychosocial stress using the Trier Social Stress Test (Study 2: n=57; 32% male, mean age: 22.43). In the presence of naturalistic stress, learning did not differ across schizotypes. However, under acute psychosocial stress, high schizotypes experienced impaired learning. Our results suggest trail-and-error learning is robust to the ebbs and flows of everyday stress for high schizotypes, however, acute stress is associated with decrements in learning. This indicates that the magnitude of stressors should be considered when designing cognitive and functional interventions for those along the psychosis continuum.

Keywords: schizotypy, stress, cognition, reinforcement, Trier Social Stress Test

Introduction

Psychotic disorders affect approximately 24 million people worldwide (World Health Organisation, 2001) and are currently considered to be one of the most debilitating and costly mental illnesses globally (Correll et al., 2010).Psychosis can bring about fear and confusion, presenting with varied, complex and distressing symptoms (Mccarthy-Jones et al., 2013). Given the burden of disease for society, patients and their families, research into psychosis has focused on identifying risk markers involved in the transition from psychological health, at risk mental state through to frank psychosis. Psychosis exists on a continuum from severe clinical disorders, such as schizophrenia and enduring maladaptive personality types such as schizotypal personality disorder, through to non-clinical expression of attenuated symptoms seen in the general population. Schizotypy is a term used to refer to a set of personality traits present in the general population (Badcock et al., 2016) and comprises oddities related to the major groups of schizophrenia-symptoms; i.e. positive (unusual thought content and perceptive experiences), negative (physical/social anhedonia, reduced emotional/verbal expressiveness and drive) and disorganised schizotypy (disorganised/confused thinking and speech) (Schultze-Lutter et al., 2019). In this way, schizotypal traits reflect the clinical symptoms of psychotic disorders, albeit in an attenuated form (Kwapil et al., 2018; Linscott & Van Os, 2013). Schizotypal traits are often regarded as phenotypic indicators of a hypothetical liability for psychosis (Fonseca-Pedrero et al., 2018), and are similarly linked to various factors of risk that predict psychotic disorder (e.g. demographic, genetic and environmental; Linscott & Van Os, 2013; Morton et al., 2016). In addition, schizotypy has been associated with deficits in cognition, poorer mental health status, lower quality of life, and reduced daily functioning (e.g. Cohen et al., 2015; Ettinger, Meyhöfer, Steffens, Wagner, & Koutsouleris, 2014; Siddi, Petretto, & Preti, 2017). This evidence makes schizotypy a potential risk marker for frank psychosis risk in the general population (Badcock et al., 2015).

There remains a debate among researchers concerning the composition and dimensions underlying schizotypy. The number of factors, characteristics, traits or behaviours included depends somewhat on the perspective assumed: categorical, dimensional, syndrome or individual differences (Grant et al., 2018). While there are three main views of schizotypy within psychosis literature, full, quasi and discontinuous dimensional models, the present paper is broadly conceptualised within the fully dimensional model, which understands psychopathology as constellations/clusters of multiple dimensions of individual differences, with psychotic illness resulting from a breakdown process within some but not all individuals at the high end of the schizotypy-continuum. As part of this model it is suggested there is continuity in symptoms between clinical and non-clinical groups (Nelson et al., 2013); with the factor structure of non-clinical individuals (schizotypes) reflecting the factor structure in those at the clinical end (Wuthrich & Bates, 2006). The fully dimensional model suggests there will be a number of individuals who will experience schizotypy without having accompanying dysfunction (Goulding, 2004). Additionally, while much of the literature has focussed on the importance of schizotypy as a risk marker for psychosis, individuals who do not transition will still benefit from efforts to improve knowledge of daily functioning in schizotypy. Schizotypal traits are of interest in and of themselves for their shaping of cognition, subjective and objective wellbeing, and daily functioning.

One factor which is known to increase the risk of transition to mental illness, and can also generally impair daily functioning, is stress (Aiello et al., 2012; Labad et al., 2015). Our day-to-day lives are laden with emotionally affective experiences, which can range from minor hassles, such as missing the bus, to major life events, such as losing a loved one. Together, such potential threats to our bodily homeostasis are referred to as 'stress' (McEwen, 2016). Stressful events ('stressors') can be both external and internal in origin, and of a physical or psychological nature (Joëls et al., 2006). Given that stress has psychological, physiological, and cognitive implications for individuals, it is of particular concern to those along the psychosis continuum, who already experience deficits in these areas.

Stress also adversely impacts those with schizotypal traits in the general population;, with reports of increased life events (Armando et al., 2018; Kocsis-Bogár et al., 2013) and childhood trauma (Velikonja et al., 2015). When considering biological correlates of stress, those with schizotypal traits have demonstrated blunted cortisol response (Walter et al., 2018), increased heart rate and greater skin conductance (Premkumar et al., 2020).

While the links between stress and the psychosis continuum overall are well documented, a consistent limitation is previous research tends to only consider one type of stress. Studies have only focussed on a single type of stress e.g. trauma (Li et al., 2015), life events/daily hassles (Tessner et al., 2011), psychosocial stress (e.g. school/job; Cullen, Day, Roberts, Pariante, & Laurens, 2015), experimentally induced acute stress (e.g. cold pressor test; Rubio et al., 2015), or biological stress (Walker et al., 2010). In addition, there is an assumption that experimentally induced stress in the laboratory, parallels everyday life stress (Zanstraa et al., 2010); for acute social stress there is some evidence this may be the case. However, stressors are heterogenous and complex therefore it is likely that differential stress effects on learning are detectable. We seek here to holistically investigate the experience of multiple naturally occurring stressors: first, “ambient” or ever-present in our day-to-day lives, and, secondly, unexpected “acute” stress, which brings about a call to action from the body’s nervous system.

While there is a breadth of evidence for an association between schizotypy and stress effects, the evidence is more mixed for the reporting of cognitive deficits in schizotypy, even in the absence of stress (Aghvinian & Sergi, 2018;). Cognitive deficits are a core feature of schizophrenia (Stuchlik & Sumiyoshi, 2014). Therefore identifying cognitive domains which are reduced or remain intact in individuals with schizotypal traits, presents an important step forward for understanding how risk for poor mental health evolves.

A number of studies indicate that spatial working memory (Hazlett et al., 2014; Park & Holzman, 1992) and reinforcement learning (Morris et al., 2008;) are impaired along the psychosis continuum. Working memory is a limited capacity system of temporary stores, which preserve information while allowing other operations to continue at the same time (Swanson, 2017). This simultaneous processing is essential for a variety of tasks, such as language comprehension, problem-solving (Carretti et al., 2013; Chuderski & Jastrzebski, 2018), and, visuo-spatial mental representations (De Beni et al., 2005; Meneghetti et al., 2011). The ability to create visuo-spatial mental representations of the world supports creative thinking, deductive reasoning, planning future actions, and learning; which are all important for daily functioning (Logie, 2014). Learning is used in our everyday lives. The ability to learn from feedback through reinforcement (trial-and-error) to optimise our behaviour is also key for daily functioning. Consequently, reinforcement learning capacity is essential to quality of life, and factors that impact reinforcement learning should be of research interest. Studies of acute stress have demonstrated negative effects on spatial working memory (Meyer et al., 2020; Olver et al., 2015), however to date the generalisation of this to naturalistic ambient stresses is limited. This is similar for reinforcement learning which has shown decrement under acute biological stress (Lighthall et al., 2013), but received little attention in reference to ambient stressors.

To summarise, schizotypy is conceptualised to exist at the non-clinical end of the psychosis continuum. Similar to their clinical counterparts, those with high schizotypal traits report psychological and functional impairments, including stress abnormalities and reduced cognitive performance compared to healthy controls. While previous research has demonstrated the link between schizotypy and stress, stress and learning, and to a lesser extent schizotypy and learning, few studies to date have examined all three commonly co-occurring factors together. Given that there is evidence for cognitive deficits along the psychosis continuum and that stress, in its many forms, affects cognitive performance (Brüne et al., 2012; Koh et al., 2006), it is important to consider these factors in conjunction to understand whether they interact to further impair a, potentially, already compromised system.

The aim of the following two studies was to investigate the potential influence of multiple types of stress on spatial trial-and-error learning in the context of schizotypal traits. Both the spatial working memory and learning elements of the spatial trial-and-error learning task tap cognitive resources important for daily functioning. Learning utilises working memory, however, is more complex, drawing on attention, elaboration, generalization, and application of the knowledge. It is therefore a useful target for investigation since a complex operation will elicit errors in individuals from the general population with varying expression of schizotypal traits. However, it is possible that different types of stress may or may not affect learning, given its fundamental role in day to day functioning. Considering different types of stress within one paper will permit the investigation of the relative robustness of learning in the context of environmental fluctuations, particularly against the backdrop of schizotypal traits which are known to sensitize individuals to stress. Therefore, the two studies will collectively permit consideration of the nature of stresses' impact on learning in two separate groups of participants.

Across both studies, we hypothesised that those with high schizotypal traits would demonstrate poorer spatial trial-and-error learning when compared to those with low schizotypal traits. In Study 1, we hypothesised that naturalistic ambient stressors would explain high compared to low schizotype differences in performance on trial-and-error learning. While in Study 2, we hypothesised that an acute psychosocial stressor would lead to elevated decrements in performance in those with high schizotypal traits when compared to low schizotypal traits.

Study 1

As a first step, we sought to explore whether ambient stressors, occurring in the daily lives of individuals, are sufficient to explain differences in performance between high and low schizotypes on a trial-and-error task. Previous research suggests that those on the psychosis continuum experience more life events and hassles (Cullen et al., 2014; Moskow et al., 2016), though they have not been measured in high schizotypes specifically so far, therefore it is possible that this heightened level of stress explains differences in learning attributable to the expression of schizotypal traits. Specifically, we were guided by the question does naturally occurring ambient stress account for differences in spatial trial-and-error performance between those with high and low schizotypal traits?

Method

Participants

Participants were recruited via word of mouth from the South-coast region of NSW and the Psychology Research Participation Scheme of the School of Psychology, University of Wollongong. To be included in the study, participants were required to be aged 18-65, have sufficient command of the English language, have no history of head trauma (with loss of consciousness) or presence of a central neurological disorder, and have no current diagnosis of a psychiatric disorder or currently using psychotropic medication. We determined our sample size in line with previous research of student samples in schizotypy and stress research. Our sample consisted of 70 healthy adults (31.43% male) aged 18-59 years (M = 22.67, SD = 6.15). Full study characteristics are reported in Table 1.

Measures

A demographics questionnaire was completed in order to assess potentially confounding factors suggested by the literature and to assess for the exclusion criteria outlined above.

Schizotypy. Assessment of schizotypal traits was conducted using the

Schizotypal Personality Questionnaire (SPQ; Raine, 1991). The SPQ is a 74-item self-report scale that provides a measure of schizotypal traits based on the DSM-III-R diagnostic criteria for Schizotypal Personality Disorder. While originally intended for the identification of Schizotypal Personality Disorder, it is one of the most commonly used self-report measures for exploring schizotypal traits in non-clinical populations (Thomas et al., 2018). This scale captures beliefs and experiences, as well as behaviours, providing both a broad measure of the construct as well as specific sub-clinical symptomology (Kwapil & Chun, 2015). While the SPQ provides both continuous and dimensional expressions of schizotypy, the present paper is interested in schizotypy as a consolidated trait. The SPQ is the most conservative estimate of schizotypy and is able to identify schizotypy levels (at the upper limit), which are seen in clinical populations (Raine, 1991).

The present work conceptualises schizotypy as a part of the psychosis continuum, and we aim to capture all features of schizotypy rather than focus on specific symptoms. As such we will be using the total score of SPQ rather than focusing on separate dimensions.

Items on the SPQ are scored with one point if participants answer yes and zero points if they answer no, with the highest score possible being 74. The initial study by Raine, (1991) reported high internal and test-retest reliabilities at 0.91 and 0.82 respectively. Cronbach's alpha for the present study was also high at .92.

To assign participants to either a high or low schizotypal traits group, a mean split of total SPQ was used. Those with mean (21) and below were allocated to the low schizotypal traits group and those above the mean were allocated to the high schizotypal traits group; the final sample included 44 participants in the low and 26 participants in the high schizotypy groups respectively.

Spatial trial-and-error learning. To assess trial-and-error reinforcement learning we used a trial-and-error learning task using spatial stimuli with reinforcement. This task was originally used by Mehta, Hinton, Montgomery, Bantick, and Grasby, (2005), and more recently, has been used to investigate neurocognition and psychotic-like experiences (Barkus, Morrison, Di Forti, & Murray, 2016). For each trial of the spatial task, participants saw two small white squares on a black screen and each trial displayed the squares in different locations relative to one another. These two squares would move location for each trial. At the beginning of the test, participants had to guess whether the stimuli presented were a pair or non-pair and indicated their decision by pressing the keyboard. After each response, the computer displayed the correct answer (‘PAIR’ or ‘NON PAIR’), in green writing if the response given by the participant was correct, or in red if the response was incorrect. There were six ‘pairs’ to learn and six ‘non-pairs’ in the task. Each pair was presented randomly a total of 10 times, so there was an opportunity to learn to distinguish the pairs from non-pairs. The feedback provided was always contingent on participants’ responses. Thus, there were 120 trials in total. The outcome measure of interest was percentage of correct responses.

There were four versions of the spatial task. Versions of the task were randomised and counter-balanced across participants to ensure that effects were not due to one task being more difficult than others. The task was presented on a Dell Latitude E6410 personal computer. Participants sat at a comfortable distance from the computer.

Naturalistic stress. To assess a broad range of naturally occurring stressors we focused on three common forms of stress: life events, daily hassles, and chronic stress in the form of perceived stress.

Life events. The number of life events experienced in the week prior to assessment were measured using the Life Events Scale (LES; Holmes & Rahe, 1967). This scale captured any major life events within the last week, which may have had an impact on their ambient stress levels. Life events are significant occurrences for example moving-house, or loss of a loved one. In addition to recording the occurrence of a life event, the LES also captured the subjective distress experienced as a result of that event using a 5-point Likert Scale.

Daily hassles. Contrastingly, daily hassles are smaller events that occur more often than life events in the course of daily life and are thought to have minor impact on the individual's life. Examples of hassles are misplacing keys, missing the bus, and inclement weather. The Daily Hassles and Uplifts Scale (DHUS; DeLongis et al., 1988) captured the number of hassles that people encounter every day. For the current study, only the hassles will be reported here.

Perceived stress. Finally in order to assess whether chronic stress levels were responsible for any observed deficits in cognitive performance, the 10-item Perceived Stress Scale (PSS; Cohen et al., 1983) was used. The PSS measures to what degree people view the events in their lives as unpredictable, uncontrollable, or overloading. The PSS is sensitive to chronic stress levels that are generated by continual life circumstances and expectant stress from future events.

Procedure

Participants were comfortably seated with the laptop placed on a desk surface approximately 20cms from the edge of the desk. Participants first completed the demographics questionnaire in which general information regarding age, sex, ethnicity, drug and alcohol use, caffeine intake, psychological and medical history, smoking preferences and factors that may affect cognitive performance (e.g. sleep problems and learning disabilities) were recorded. Once the demographics of the participant were captured and exclusion criteria was checked, trait scales were administered including the SPQ and state scales including the DHUS, LES and PSS. Once the scales had all been completed, participants were presented with the spatial trial-and-error learning task. This study received approval from the University of Wollongong, Human Research Ethics Committee with participant giving informed consent prior to commencing the study.

Statistical analyses

All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 21. For missing data points, we used sample mean value replacement. To limit the number of tests performed and thus the chances of a Type II error, the minimum number of analyses was used. Alpha level for all analyses was set at .05, estimated marginal means and standard errors are reported.

We compared high and low schizotypal trait groups on descriptive variables such as sex, age, smoking habits, and employment using the Pearson χ^2 test for categorical variables or Student's t test for continuous variables, as appropriate. We then moved on to the group comparison of the various stress variables. We used independent groups t-tests to assess the relationship between schizotypy (IV) and daily hassles, life events, subjective distress following life events, and perceived stress each as dependent variables.

Following group comparisons, we then began our main set of analyses using a Group x Task x Stimuli repeated measures ANOVA. There were two within subject variables of interest: five levels of Task block (to investigate learning) and two levels of Stimuli type (pair or non-pair) and schizotypy group (high or low) was the between subjects variable. Once the initial model had been run to determine effects of schizotypy group, stress variables which were significant in our group comparisons were entered into the model as covariates and the model was rerun to determine whether there were any changes in statistical outcomes once stress was accounted for. Where relevant, independent and paired samples t-tests were used post-hoc to determine where significant differences lay. For any violations of sphericity, Greenhouse-Geisser corrected F-values and degrees of freedom were used. Effect sizes were reported using partial eta square for F-tests, Cohen's *d* for paired t-tests and Hedge's G for independent t-tests with uneven sample sizes. Finally, bivariate Pearson's product moment correlations (*r*) assessed the relationship between significant stress variables from the group comparison and learning at each Block of the task within schizotypy group to assess whether a relationship was present between stress and learning in general.

Results

Group comparison on descriptive variables

Descriptive and group comparison statistics can either be found in Table 1 or in text for more complex analysis. There were no significant differences between the groups based on age, sex, employment, or relationship status. There was a significant difference between these groups on total SPQ score (t(68) = 10.966, p <.001, g=3.017).

[Insert Table 1 here]

Group comparison of stress variables

Independent samples t-test showed that those in the high schizotypal trait group reported more daily hassles (t(38.989) = 3.21, p =.003, g=.830) and life events (t(62)= 2.24, p =.014, g=.484) than the low schizotypal traits group. There were no significant differences between high and low schizotypes for either life event distress (t(62) = 1.65, p =.051) or perceived stress (t(68) = -1.096, p = .277).

Trial-and-error learning

Main effect of task. There was a significant effect of the task, with participants improving in accuracy over the course of the five task blocks (Block1: 0.537(0.010); Block2: 0.519(0.009); Block 3: 0.572(0.013); Block4: 0.596(0.013); Block5: 0.642(0.015); F(3.378, 229.678) = 20.037, p <.001, η^2_p =.228). Follow-up analyses are presented in Supplementary file 2 and demonstrate participants as a cohort learned across the course of the task.

Main effect of stimuli. A significant main effect of stimuli was present where overall, participants learned to correctly identify the pairs (.635 (0.011)) better than non-pairs (.511 (0.012); F(1,68) = 51.362, p = <.001, η^2_p =.430).

Main effect of schizotypy. There was no main effect of schizotypy group on performance F(3.4, 204.014) = .233, p =.895.

Stimuli x schizotypy. There was no stimuli x schizotypy group interaction $F(1,60) = .324$, $p = .571$.

Stimuli x task. A significant interaction between stimuli and task was found ($F(4, 272) = 7.865$, $p < .001$, $\eta^2_p = .104$). While learning occurred in both stimuli conditions, the rate of learning for non-pairs (Block1: .459(.017); Block2: .444(.014); Block3: .488(.018); Block4: .537(.020); Block5: .627(.021)) appears to be greater and more consistent than the pairs (Block1: .616(.015); Block2: .593(.014); Block3: .656(.020); Block4: .655(.015); Block5: .656(.018)). Follow-up analyses are presented in Supplementary file 2 and suggest that while performance is consistently better on the pairs condition, more learning occurs across the task for the non-pairs condition.

Stimuli x task x schizotypy. There was no significant interaction between stimuli and task across schizotypy groups $F(4,272) = 1.325$, $p = .261$.

Addition of stress covariates. As daily hassles and life events were the only variables to have significant group differences, they were the only covariates entered into the model. Upon the addition of the covariates, all previously significant effects remained (although are lessened). Therefore, daily hassles and life events could not explain the task effects reported above. In addition, we considered whether there was a significant association between daily hassles, life events, and learning in general however there were no significant correlations for total % correct, or % for pairs or non-pairs.

In sum, although the expected task effects were present, there were no significant differences in trial-and-error performance between high and low schizotypes;

in addition, including daily hassles and life events as covariates did not alter the significance of the analyses performed.

Study 2

In Study 1 high schizotypes did report more life events and daily hassles. However, contrary to our hypothesis high and low schizotypes did not differ in their trial-and-error spatial learning in Study 1 and the inclusion of life events and daily hassles as covariates did not alter the significance of the model. Therefore, our second study sought to investigate whether more intense and acute experiences of psychosocial stress would be associated with decrements in a system that seems robust against the ambient "noise" of daily life. Specifically, we investigated the research question does experimentally induced psychosocial stress affect trial-and-error performance more in high schizotypes than low schizotypes?

Method

Participants

For Study 2 we recruited 57 participants (32.76% male) using the same methods as Study 1. Participants were aged from 18-46 years ($M = 22.43$, $SD = 6.55$) and were recruited as part of a larger study investigating the effects of experimentally induced stress on acute cortisol response and cognitive outcomes. Our cortisol results are reported elsewhere (Walter et al., 2018). In addition to the inclusion criteria of Study 1, participants were excluded if they had an endocrine disorder or were taking any medication which would alter cortisol release.

Measures

The SPQ and the trial-and-error task from Study 1 were also used in the second study. Internal consistency for the SPQ was again high with Cronbach's alpha at .94. As participants completed the trial-and-error task twice as part of this paradigm, to avoid practice effects from using the same materials, participants received a different version of the task each time they completed it. Consistent with Study 1, we separated our groups by using a mean split, creating low (23 and below) and high (24 and above) schizotypal trait groups, the final sample included 24 participants in the low and 33 participants in the high schizotypy groups respectively.

Experimentally induced stress. The Trier Social Stress Test (TSST) (Kirschbaum et al., 1993) was used to induce psychosocial stress. The TSST is a robust measure for inducing moderate psychosocial stress (Ciufolini et al., 2014). It is an experimental paradigm which involves a baseline period, an anticipation phase, stress-induction phase, and back-regulation phase. The TSST typically takes place in two rooms, Room A as the Preparatory Room and Room B as the Testing room. Experimental sessions ran between 1.00 and 5.00 pm, after arrival participants completed questionnaires in Room A, this acted as the baseline resting period. The stress-induction phase of the TSST took place in Room B and involved an anticipation period (10min), followed by a test period (10 min). During the test period participants were required to give a 5-minute speech designed to convince a panel of neutral interviewers that they were the best candidate for their 'dream job'. They were also told that their speech would be audio and video recorded so that the judges could analyse their non-verbal communication skills following the task. A video camera was placed in the room, but it was not switched on, although participants were not aware of this. Immediately following the speech, participants were asked to complete a 5- minute verbal mental arithmetic task in front of the panel. Once the stress induction phase was complete, participants returned to Room A where they were monitored for an additional 60 minutes post-task as part of the back-regulation phase, and then debriefed. The full TSST protocol and running procedure are provided in Supplementary file 1.

Procedure

As part of a larger study investigating the effects of experimental stress on the general population, participants completed all materials in one sitting, with the researcher present at all times. The session lasted ~120mins and each participant was tested individually. After gaining written consent, participants first completed the demographics questionnaires, and then they completed the SPQ. Participants then completed the pre-stress trial-and–error task. Following this, they were immediately presented with the stress induction task (TSST), before completing the post-stress trial-and-error task. We then debriefed participants about the nature of the study and compensated them for their time. As with Study 1, ethical approval was provided by the University of Wollongong Human Research and Ethics Committee and informed consent was obtained.

Statistical analyses

All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 21. For missing data points, we again used sample mean value replacement. The minimum number of analyses were used to limit the chances of a Type II error and we set our alpha level for all analyses at .05, we also report estimated marginal means and standard errors.

As with Study 1, we began with our group comparison of descriptive variables by taking our high and low schizotypal trait groups and comparing them on sex, age, smoking habits, and employment, using the Pearson χ^2 test for categorical variables or Student's t test for continuous variables, as appropriate.

We then moved on to our main analyses for Study 2 which involved a 5x2x2x2 repeated measures ANOVA. There were three within subject variables: five levels of task block (to investigate learning), two levels of stimuli type (pair or non-pair), and two levels of stress induction (pre and post). The two schizotype groups formed the between subjects variable. Independent and paired samples t-tests were used post-hoc to investigate any significant main effects. For any violations of sphericity, Greenhouse-Geisser corrected F-values and degrees of freedom were used. In line with Study 1, effect sizes were reported using partial eta square for F-tests, Cohen's *d* for paired t-tests and Hedge's G for independent t-tests with uneven sample sizes.

Results

Group comparison on descriptive variables

The groups did not differ significantly based on age, sex, employment, or relationship status.. Once again, there was a significant difference in SPQ scores between the groups where the high schizotypal traits group scored higher than the low group ($t(55)= 11.104$, $p<.001$, $g = 2.938$). Full descriptive characteristics can be found in Table 2.

[Insert Table 2 here]

Trial-and-error learning

Main effect of task. There was a significant effect of the task, with participants learning over the course of the five task blocks (Block1: .517(0.010); Block2: .574(.015); Block 3: .618(.019); Block4: .647(.017); Block5: .644(.019); $F(3.094,163.998) = 32.605$, $p <.001$, $\eta^2_p =.381$). Follow-up analyses are presented in Supplementary file 2.

Main effect of stress induction. There was no main effect of stress induction on performance on the trial-and-error task $F(1,163.988) = .472$, $p = .495$).

Main effect of stimuli. A significant main effect of stimuli was present where overall, participants learnt to correctly identify the pairs (.651 (.016)) better than non-pairs (.549 (.017); $F(1,53) = 29.057$, $p <.001$, $\eta^2_p =.354$).

Main effect of schizotypy. There was no main effect of schizotypy group on performance $F(1,53) = .406$, $p = .527$.

Task x schizotypy. As shown in Figure 1, a significant interaction between task and schizotypy was found where accuracy for participants in the low schizotypy group was better than the high schizotypy group ($F(3.094,163.998) = 2.596$, $p = .027$, $\eta^2_p =.047$).

To investigate this, we computed new variables (the aggregated average of pre and post stress performance at each Block) in order to be able to assess task effects as a whole. Post-hoc tests revealed that between groups, low schizotypes performed significantly better than the high schizotypes in Block5 only ($t(53) = 1.930$, $p = .026$, $g = .528$). This suggests that overall. the low schizotypes learned more consistently over time.

We then looked at within group differences. Using paired samples t-tests there were significant within group differences for the low schizotypes where performance improved between Block1 and Block2 ($t(22) = 3.360$, $p = .001$, $d = .673$), Block3 ($t(22) = 4.878$, $p < .001$, $d = 1.126$), Block4 ($t(22) = 6.122$, $p < .001$, $d = 1.381$), and Block5 ($t(22) = 7.269$, $p < .001$, $d = 1.532$);between Block2 and Block3 ($t(22) = 3.062$, $p = .002$, $d = .436$), Block4 ($t(22) = 4.160$, $p < .001$, $d = .690$), and Block5 ($t(22) = 5.750$, $p < .001$, $d = .835$); and from Block3 – Block5($t(22) = 2.44$, $p = .012$, $d = .402$).

There were also within group differences for the high schizotypes, where performance improved between Block1 and Block2 ($t(31) = 2.550$, $p = .008$, $d = .512$), Block3 ($t(31) = 3.833$, $p < .001$, $d = .748$), Block4 ($t(31) = 6.915$, $p < .001$, $d = 1.170$), and Block5 ($t(31) = 4.055$, $p < .001$, $d = .871$); from Block2 to Block3 ($t(31) = 2.309$, $p = .014$, $d = .270$), Block4 ($t(31) = 4.999$, $p < .001$, $d = .270$), and Block5 ($t(31) = 1.885$, $p = .034$, $d = .332$); and Block3 – Block4 ($t(31) = 2.162$, $p = .017$, $d = .240$). Contrastingly, performance worsened between Block4 – Block5 ($t(31) = -2.130$, $p = .020$, $d = .035$) for high schizotypes.

[Insert Figure 1 here]

Stimuli x schizotypy. There was no significant stimuli x schizotypy group interaction $F(1,53) = 1.883$, $p = .08$.

Induction x schizotypy. The interaction between stress induction and schizotypy group was non-significant $F(1,53) = .472$, $p = .460$.

Stimuli x task. As shown in Figure 2, a significant interaction between stimuli and task was found $F(3.060, 162.160) = 9.894$, $p < .001$, $\eta^2_p = .157$. Similar to Study 1, while performance was consistently better in the pairs condition, the rate of learning for non-pairs was greater and more consistent than the pairs. Follow-up analyses are reported in full in Supplementary file 2.

[Insert Figure 2 here]

Stimuli x task x schizotypy. There was no significant interaction between stimuli and task across schizotypy groups $F(3.060,162.160) = .733$, $p = .268$.

Stimuli x induction. There was no significant interaction between stimuli and stress induction on learning $F(1,53) = .101$, $p = .378$.

Stimuli x induction x schizotypy. There was a significant interaction of stimuli with stress induction and schizotypy group ($F(1,53)=6.213$, $p = .008$, $\eta^2_p = .105$). To investigate this, we considered each variable from a between and within groups perspective, to tease apart this complex three-way interaction. We began by computing averages for pairs pre and post stress, and non-pairs pre and post stress, and also a single aggregated average for pairs and non-pairs.

We first considered the effect schizotypy may have on the significant interaction observed. When splitting the sample by schizotypy, comparisons for pre versus post stress, performance was significantly lower post stress induction for high schizotypes in the pairs condition only ($t(31) = -1.683$, $p = .05$, $d = .27$). There were no significant differences in performance pre-post stress for high schizotypes in the non-pairs condition ($t(31)$ .555, $p = .583$), or low schizotypy for either stimulus condition (Pairs: $t(22) = .802$, $p = .431$; Non-pairs $t(22)$ -1.418, $p = .085$).

The post hoc analyses thus far have been based on average performance. We also considered the change in performance across the task itself. To do this we computed a change score from Block 1 to Block 5 for pairs and non-pairs pre and post stress, and a grand average change score for pairs and non-pairs which provided overall change in performance. We then used paired samples t-tests to consider whether stress influenced change in performance pre vs post induction both at a cohort level and within schizotypal groups.

To begin we used an independent sample t-test. Low schizotypes performed significantly better than high schizotypes in the pairs condition both pre stress (low: $M = 0.104$, $SE = 0.038$, high: $M = 0.008$, $SE = 0.034$; $t(55) = 1.878$, $p = .033$, $g = .497$) and post stress (low: $M = 0.127$, $SE = 0.045$, high: $M = 0.008$, $SE = 0.037$; $t(53) = 2.061$, $p = .022$, $g = .555$).

We then used paired samples t-tests and observed no difference in the change in performance as a function of stress induction for the cohort as whole (Pairs: $t(54) = .550$, $p = .585$; Non-pairs: $t(54)$.-1.00, $p = .322$). This indicates that stress induction alone is not explaining the significant interaction observed in the ANOVA. We then spilt the file by schizotypy. For change in learning following the stressor, we see the low schizotypy group saw an improvement in performance for pairs ($M = .0246$, $SE = 0.031$) and a decrement in performance of non-pairs ($M = -.042$, $SE = 0.029$), but this change was not significant ($t(22) = -1.555$, $p = .067$).

For the high schizotypal group however, we see the opposite trend, with performance worsening for the pairs ($M = -.038$, $SE = 0.022$), while performance for non-pairs improved ($M = .014$, $SE = 0.025$) and this difference in performance was significant ($t(31) = 1.990$, $p = .028$, $d = .382$).

Task x induction. There was no significant interaction between task and stress induction on learning $F(3.034,160.793) = .087$, $p = .484$.

Task x induction x schizotypy. There was no significant interaction between stress induction and task across schizotypy group $F(3.034, 160.793) = 1.244$, $p = .148$.

Stimuli x task x induction. There was no significant interaction between stress induction, task and stimuli $F(3.403, 180.369) = .935$, $p = .217$.

Stimuli x task x induction x schizotypy. There was no significant interaction between stress induction, task and stimuli across schizotypy group $F(3.403, 180.369) = .720$, $p = .279$.

Discussion

The two studies herein considered whether high schizotypes differed from low schizotypes on trial-and-error learning and whether stress explained or exacerbated group differences in performance. We hypothesised that those who reported higher schizotypal traits would show reduced accuracy in trial-and-error learning. However, the results were not as straight forward as we first supposed. In the first study high schizotypes did report more hassles and life events than low schizotypes; although there were no differences for perceived stress or for the stress associated with the life events people reported. For trial-and-error learning, high and low schizotypes did not differ from one another in their performance, although task effects on performance were evident as expected, learning did occur and was preferential for the pairs compared to the non-pairs. However, we found that hassles and life events, when placed as a covariate did not change the overall pattern of results. Therefore, our hypothesis was not supported.

In our second study, we saw the expected effects of the task and replicated our task findings from Study 1. In addition, we also observed a group difference in performance on the trial-and-error learning task, with low schizotypes performing significantly better by the final block of the task than high schizotypes. Within both groups there was evidence of significant learning across the task, however within the high schizotypes overall performance decreased between the penultimate and final block. This perhaps reflects difficulties in sustaining attention throughout the task.

Furthermore, in Study 2, we found that the acute stress induction did effect performance, but only as an interaction with both schizotypy and the stimuli being learned. When we consider performance across stimuli, we see that high schizotypes were less accurate in learning pairs following acute social stress, while low schizotypes' accuracy did not change. Low schizotypes performed better on overall learning for the pairs pre- and post-stressor. The stress induction did not lead to significant changes in performance within the low schizotypes, however for high schizotypes stress decreased learning for pairs and increased non-pairs learning. Thus, our hypothesis for Study 2 was partially supported since there were performance differences between high and low schizotypes and it was the effect of an acute stressor which brought these to the fore, although it appears that the type of stimuli being learned is important.

Previous research with patients who have schizophrenia demonstrate that these individuals have impaired learning ability (Waltz et al., 2011; Waltz & Gold, 2007; Wood et al., 2002). However, the research considering learning in schizotypy is mixed, at times suggesting that some types of learning are impaired compared to average/low schizotypes: e.g. associative learning (Haselgrove & Evans, 2010; Moore et al., 2011), incidental learning (Burch et al., 2006), overshadowing (Granger et al., 2012), and latent inhibition (Granger et al., 2016). While others report no difference between low and high schizotypes (e.g. Humpston, Evans, Teufel, Ihssen, & Linden, 2017). For the related cognitive ability of spatial working memory, research suggests that high schizotypes experience impaired performance for tasks in this area (Park et al., 1995). Our results also present a conflicting view of spatial learning in schizotypy. The increased number of data points in Study 2 for each participant may have increased the power available for statistical analysis to explain why schizotypy group did not interact with overall learning in Study 1.

Our results add to existing literature in considering how different types of stress might impair learning in high schizotypes. Previous research suggests stress impairs learning ability (LePine et al., 2004; Römer et al., 2011). For trial-and-error learning, the acute stressor, but not the naturalistic stressor, perturbed performance. This presents a few possibilities: first, the mechanisms driving the effects on cognition of the two stressors may be different; second there may be a quantitative difference in the effects of these stressors. Thirdly, those with schizotypal traits may be able to complete complex cognitive operations when their systems are not perturbed; however, in the presence of stressors, which compromise their vulnerable systems, their cognitive performance diverges from those with average or low schizotypal traits to reflect the reduced performance reported in patients. Understanding whether high schizotypes use different strategies or draw on more resources to successfully complete learning tasks compared to average or low schizotypes could be an important avenue of work for future research. This could also help to explain why ambient stress did not change performance on the trial and error learning for high schizotypes, while acute stress did.

Learning is a complex operation which is used in an everyday setting to inform decision making even under conditions of uncertainty. Gaining an appreciation of the limits and strategies used to successfully complete learning along the psychosis continuum could point to important differences between clinical and non-clinical groups as well as inform interventions designed to improve completion of daily tasks.

An alternative explanation for the results could be gleaned from physiological differences between how high and low schizotypes respond to stress. Acute stress activates the parasympathetic nervous system as a call to action. Recent research has shown that in response to acute stress, high schizotypes report the same subjective experience of stress as those with low schizotypal traits, however demonstrate a blunted cortisol response compared to low schizotypes (Walter et al., 2018). Thus, those with high schizotypal traits, do not display the same adaptive physiological response following acute stress. Perhaps what we are seeing here is that under acute stress high schizotypes are not able to call into action resources that allow the amelioration of stress and maintenance of optimal cognitive functioning - which is why we observe reduced learning to acute stress rather than ambient stress (which should be less physiologically arousing). Alternatively, it is possible that higher stress reactivity along the psychosis continuum (Dombrowski et al., 2014), including high schizotypes, ensures that physiological stress responses are more chronically taxed. This would mean that when confronted with an acute stressor, the already depleted resources in high schizotypes are not able to physiologically prepare the body and mind to manage the additional acute stressor against the higher arousal baseline.

It may also be that the key element linking physiological and cognitive responses to stress is the psychological appraisal of the experience itself. For example, when understanding the effects of trauma on psychopathological outcomes, cognitive theorists suggest it is not the event itself which matters most, rather it is the interpretation and attributions formed by the individual after the traumatic experience (Sherrer et al., 2015). Appraisals of circumstances may also be influenced by individual differences such as personality factors. Whether or not we notice or experience minor inconveniences as hassles could be predicted by temperament (e.g. neuroticism) or how we are feeling on that particular day (state factors such as mood). In contrast, an acute stress is by its magnitude universally noticeable. Appraisals and attributions will be important for many life events, which may be positive life changes in the longer term but can still induce physiological stress e.g. moving-house, having a baby, divorce. The appraisals and attributions formed by an individual provide the psychological learning environment against which all future stressors are experienced. Therefore, perhaps future studies, need to consider the importance of the psychological framing of experiences to cognitive effects and physiological arousal to a stressor.

A finding of interest was the difference in learning between stimuli. While high schizotypes had generally lower performance overall, there was an improvement in their accuracy for non-pairs. Non-pairs were viewed as distractors in the task and were expected to be the more difficult stimuli to correctly identify (Mehta et al., 2005). An explanation for why high schizotypes performed better for non-pairs may be impaired inhibitory control (Ettinger et al., 2015). Poorer ability to ignore distractors (inhibitory control) has been demonstrated across the psychosis continuum (Ettinger et al., 2018). By engaging the parasympathetic nervous system through stress, an individual primed to search for threat, and with less ability to suppress distracting stimuli, may have greater capacity to attend to these "distractors" and consequently keep them in mind compared to low schizotypes.

Finally, a further potential explanation for the differences in performance across acute and ambient stress may lie in dopamine response. In particular, the differences in performance across pairs and non-pairs for those with high schizotypal traits may lie in reinforcement learning. The spatial learning task involved receiving feedback about the "correctness" of responses and using this feedback on future trials. Dopamine neurons are known to code reinforcement prediction errors, which are an essential signal in a number of reinforcement learning models (Frank, Seeberger, & O'Reilly, 2004). Dopaminergic disturbances are detectable in psychotic disorders (Laruelle et al., 2003), with research in the last thirty years demonstrating that these abnormalities are also present prior to illness onset in clinical high risk individuals (Mizrahi et al., 2014), and increasingly in the prodrome as individuals transition into psychosis (Howes et al., 2011).

Increases in dopamine are associated with positive feedback for Go signals during task completion, while NoGo or negative feedback relates to dips in dopamine signalling (Frank, 2005). Colloquially this could explain why it is easier to learn what something 'is' rather than 'is not'. Given that high schizotypes may have higher levels of subcortical dopamine signalling, it is possible that they do not experience the same magnitude of decreases in dopamine following negative feedback, therefore they are more readily able to learn the non-pairs compared to average and low schizotypes (Mohr & Ettinger, 2014). Future studies considering learning along the psychosis continuum should include measures of dopamine tone and signalling to assist in clarifying the heterogeneous findings within this area (Mohr & Ettinger, 2014).

This present study has a number of limitations. First, due to relatively small sample sizes our ability to show significant differences may be limited, some trend results may reflect that the study is underpowered. However, while small, sample size was comparable with other studies examining spatial learning and working memory (Barkus et al., 2016;). The sample size becomes more of an issue given the inconsistency between the two studies for the differences in performance by schizotypy group. In saying this, the two studies had approximately similar group sizes and we replicated the task effects, yet we would like to see these results replicated in a larger sample.

Another possible study limitation is the number of trials within the trial-and-error learning task used in this study. Future studies need to include measures of general intelligence and basic units of cognitive functioning such as sustained attention and working memory. Given the complex nature of spatial trial-and-error learning it draws on a number of areas of cognition, understanding which of these are compromised by schizotypy and stress could assist in dissecting the inconsistency in existing findings and the possible differences between our two study samples. In a similar manner, perhaps we also need to consider whether any demographic differences between the samples used in the two studies may have accounted for the lack of schizotypy effects in Study 1. A future study design needs to include the same participants in a naturalistic consideration of stress alongside an experimentally induced stressor such as the TSST. In this way, it will be possible to address whether acute stress and naturalistic stress responses are related.

We must also consider the way in which we captured the stressors included here. While Study 2 was able to capture stress in an ‘online’ sense, where we could assess the direct impact after the acute stressor, this was not possible with Study 1. Study 1, while able to capture multiple stressors occurring in daily life, could only do so from a retrospective or 'offline' perspective. As such, we can only report that they do not relate to trial-and-error learning. As such future research which can assess daily hassles and life events in an online way (perhaps through ambulatory assessments) would allow us to investigate whether ambient stressors such as these directly impact learning.

Lastly, although we tried to take into account different types of stress, we were not able to consider the temporal relationship between the different stressors. For instance, while hassles might not influence cognition in small amounts there could be a cumulative effect for them to compromise cognitive capacities. In addition, life events and hassles are likely to co-occur, so again it would be beneficial to begin to understand the temporal relationship between these types of stressor and how they cumulate to compromise cognitive and psychological resources. Studies need to be specifically designed to consider the temporal link between different stressors to disentangle the colloquial term "the straw that broke the camel's back".

The current results have important implications for understanding potential markers that differentiate individuals on the psychosis continuum From the present study we can conclude there is likely not a single relationship between stress and cognitive outcomes. Rather, depending on the types of stress, cognition will be differentially compromised in schizotypes. Generally, spatial trial-and-error learning capacity seems intact in individuals with high schizotypy. Stresses of everyday life do not account for variation in learning. It is only when the stress reaches a threshold of intensity (acute) that learning is affected.

Declaration of interest statement

The authors declare no financial and personal relationships with other people or organizations that could inappropriately influence (bias) the current work. Conflicts of interest: none.

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Table 1.

Descriptive characteristics for participant groups for study one (%, means ± SDs).

Characteristic	Low schizotypes (n = 44)	High schizotypes (n = 26)	*t*-test/ χ^2
Demographics			
Age (years)	23.27 (7.38)	21.65 (2.98)	*ns*
Sex	32% male	46% male	*ns*
Relationship status			
Single	52%	42%	*ns*
Relationship	43%	57%	*ns*
Married/Defacto	4%	-	*ns*
Separated/Divorced	-	-	*ns*
Employment			
Student	100%	100%	*ns*
Casually employed	40%	33%	*ns*
Part-time employed	32%	16%	*ns*
Full-time employed	8%	16%	*ns*
Self-employed	4%	8%	*ns*
Unemployed	8%	25%	*ns*
Schizotypal Personality Questionnaire Total schizotypy	12.8 (5.89)	34.58 (9.06)	$t(68) = 10.966$***
Stress questionnaires			
Perceived social stress	28.39 (4.7)	29.62 (4.23)	*ns*
Life events	3.42 (2.57)	4.68 (2.68)	$t(62) = 2.24$*
Life event stress	8.86 (1.31)	12.09 (1.91)	*ns*
Daily hassles	26.47 (2.67)	44.92 (5.08)	$t(38.989) = 3.21$**

*p<.05, **p<.01, ***p<.001

Table 2.

Descriptive characteristics for participant groups of study two (%, means ± SDs).

Characteristic	Low schizotypes (n = 24)	High schizotypes (n = 33)	t-test/ χ^2
Demographics			
Age (years)	22.5 (5.66)	22.18 (7.08)	*ns*
Sex	23.5% male	31.8% male	*ns*
Relationship status			
Single	58.8%	40.9%	*ns*
Relationship	35.3%	50.0%	*ns*
Married/Defacto	5.9%	-	*ns*
Separated/Divorced	-	9.1%	*ns*
Employment			
Student	100%	100%	*ns*
Casually employed	47.1%	27.3%	*ns*
Part-time employed	23.5%	13.6%	*ns*
Full-time employed	29.4%	-	*ns*
Self-employed	-	4.5%	*ns*
Unemployed	%-	9.1%	*ns*
Schizotypal Personality Questionnaire			
Total schizotypy	11.08 (6.84)	34.76 (8.66)	$t(55) = 11.104$***

Note: *p<.05, **p<.01, ***p<.001

Figure captions

Figure 1. Interaction between SPQ and total task performance across task blocks with estimated marginal means and standard errors.

Figure 2. Rate of learning as a function of stimuli type across task blocks with estimated marginal means and standard errors.

Figure 3. Interaction between stimuli and stress induction across schizotypy group with estimated marginal means and standard errors.