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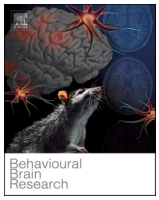

Schizotypy dimensions do not predict overshadowing

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ABSTRACT

When two cues are presented together and reliably predict an outcome (AB-O1) an "overshadowing" effect is typically observed. That is, the relationship between these cues and the outcome is learned about less well than a cue presented on its own with an outcome (e.g., C – O1). The current study sought to explore the relationship between overshadowing and the positive and negative dimensions of schizotypy. A total of 256 participants completed an overshadowing procedure embedded within a causal judgement task and the Short Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE) which measured the different dimensions of schizotypy. A unilateral overshadowing effect was observed, however, none of the dimensions of schizotypy predicted the magnitude of this effect. These results are the first to demonstrate this finding using an appropriately powered sample and reveal that a tendency to experience symptoms of schizophrenia does not impact upon the overshadowing effect.

When a compound of two or more cues is presented together prior to the delivery of an outcome, a cue competition effect is typically observed (e.g., [20,21,40,53]; although see [50]). That is, learning about the relationship between one of the cues and the outcome restricts learning about the other cue-outcome relationship. The study of two cue-competition effects in particular has come to dominate the associative learning literature: blocking (e.g., [20]) and overshadowing (e.g., [40]). In a blocking experiment, one cue is established as a reliable predictor of an outcome (i.e. A - O1) before being presented in a compound with a second cue (i.e., B) which is predictive of the same outcome (i.e., AB – O1). In such instances cue A typically "blocks" learning about the relationship between cue B and the outcome [20,21]. In an overshadowing experiment, trials are given in which a cue is presented in isolation and followed by an outcome presented alone (A – O1); and on other trials a compound of two different cues is presented and followed by the same outcome (BC – O1). Following this training, the relationship between cue A and the outcome is typically learned about better than the relationship between each of the compound cues (B and C) and the outcome (i.e., reciprocal overshadowing) or just one of the compound cues (B or C) and the outcome (i.e., unilateral overshadowing; [33]). Blocking and overshadowing have been demonstrated using a variety of different experimental paradigms in a wide range of species, including bees, rats, pigeons and fish [23,5,33,54]. They have also been instrumental in the development of influential models of learning (e.g.: [46]), and in particular models of learning that emphasise the role of learned changes in stimulus salience or attention (e.g.: [8,32,41]).

Cue competition effects have also been reliably demonstrated in healthy human participants (e.g.: [26,43,52]). However, a number of studies reveal that these effects are disrupted in schizophrenic populations. For example, Jones et al. (1992) conducted a blocking experiment with a healthy group of participants and a group of patients diagnosed with schizophrenia. The healthy participants demonstrated the standard blocking effect following completion of a contingency learning task. Crucially, however, patients with acute schizophrenia did not show this blocking effect. Similar studies using a range of experimental procedures have also reported comparable effects ([12,36,37] although see [18,49]). These findings are important as they suggest that performance on cue interaction tasks can serve as a possible bio-behavioural marker for schizophrenia. As such, these tasks have potential to serve as screening tools for susceptibility to schizophrenia and allow exploration of the impact of schizophrenia symptoms on learning and behaviour [36]. To explain the findings of Jones et al. [19] and others, it has been suggested that patients with schizophrenia experience an impairment in their ability to selectively attend to and discriminate between irrelevant and relevant stimuli due to a state of

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"aberrant salience" [22]. This state of aberrant salience is deemed to arise because of a hyperdopaminergic brain state which results in an aberrant allocation of salience to irrelevant environmental stimuli. For example, in the context of a blocking task the 'blocked' cue, B, is typically deemed an irrelevant stimulus as it does not provide any new information about the presence of the outcome relative to cue A. It is therefore inefficient to focus attentional resources on learning about the relationship between the blocked cue and the outcome. Yet, schizophrenic patients continue to learn about the relationship between the blocked cue and the outcome (e.g., Jones et al., 1992), which is consistent with the idea that an aberrant allocation of salience to the blocked cue has occurred. Although there are reports of a disruption in overshadowing in animal studies following administration of dopaminergic drugs (e.g.: [39,38]), to our knowledge no such studies have explicitly assessed the relationship between schizophrenia and overshadowing. Some studies (e.g., [19,37]) exploring the relationship between blocking and schizophrenia have, however, included overshadowing as a control condition and showed that patient status does not interact with overshadowing [19].

Impairments in blocking are not solely restricted to patients with schizophrenia. Studies with healthy participants with schizophrenia-like personality traits produce comparable effects [14,15,31,48]. In such studies, participants complete "schizotypy" questionnaires such as the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE; [34,35]) which score their tendency to experience symptoms of schizophrenia such as cognitive disorganisation (e.g., difficulty in concentrating/making decisions), unusual experiences (e.g., seeing things that are not there, magical ideas/beliefs), impulsive non-conformity (e.g., reckless and anti-social behaviour) and introvertive anhedonia (e.g., difficulty in experiencing pleasure). These schizotypy measures have been developed on the premise that schizophrenia represents an extreme end on a continuum of a multidimensional set of personality traits referred to as schizotypy [6]. Whilst those that meet clinical diagnosis criteria for schizophrenia will be at the extreme end of these measures, there will be many healthy participants who vary on the continuum to differing degrees. Administering schizotypy measures therefore allows the study of the degree to which schizophrenia symptoms impacts upon learning with nonpatient populations, thus circumventing some of the confounds associated with testing patients (e.g., variations in medication).

Several studies have reported that, like people with schizophrenia, healthy participants scoring high in schizotypy can also exhibit a disruption in blocking. For example, Haselgrove and Evans [16] required participants to imagine they were a food health-and-safety inspector at a hospital. Participants were presented with foods and were then informed whether a patient experienced food poisoning. In a first stage of training, one food (A – O1) reliably predicted food poisoning whilst another predicted its absence (C – noO1). In the second stage of training both foods predicted food poisoning, however, they were also paired with a novel cue (i.e., AB – O1 and CD – O1). During a final test stage participants provided safety ratings for the foods. Participants scoring low in the O-LIFE dimension of introvertive anhedonia demonstrated a blocking effect (i.e., they provided lower ratings to stimulus B, than D). However, for participants scoring high in introvertive anhedonia there was an attenuation of blocking, a finding consistent with Jones et al. (1992). Within the task employed by Haselgrove and Evans [16] it was also possible to assess the impact of schizotypy on overshadowing, as an elemental cue (K – O1) and a compound cue (EF – O1) were also presented to participants during Stage 2 training. Interestingly, overshadowing did not differ between the high and low scoring groups of introvertive anhedonia. This is somewhat unexpected given that associative learning models typically assume a common underlying mechanism for cue competition phenomena such as blocking and overshadowing (e.g., [8,24,41,32,46]).

Two further studies have examined the relationship between overshadowing and schizotypy which, interestingly, have produced conflicting results. Granger et al. [13] examined the relationship between schizotypy, as measured by the O-LIFE, and overshadowing in a geometric learning task where participants were tasked with identifying the correct corner of a shape to select. Participants scoring higher on the "unusual experiences" subscale of O-LIFE demonstrated attenuated overshadowing. The other three dimensions of the O-LIFE, however, did not correlate with overshadowing. In contrast, however, Pickett et al. [42] did not observe any relationship between overshadowing and any schizotypy dimensions using the short form O-LIFE and two different types of tasks to capture overshadowing, those being the food-allergist task and a Lego-building task. In both studies, however, relatively small sample sizes were used ($N < 70$) which may account for the conflicting results. It is well established that underpowered studies can lead to both false positives and false negatives leading to low reproducibility [11,2]. Indeed, Pickett et al. [42] noted that the analyses they performed in their attempt to conceptually reproduce findings from Granger et al. [13] is not typically advised due to insufficient power.

As such, the current study sought to examine the relationship between schizotypy dimensions and overshadowing with an appropriately powered sample using the short form Oxford-Liverpool Inventory of Feelings and Experiences [35] and the food allergist task, which is one of the most commonly used associative learning tasks to examine cue competition effects (e.g., [25,51]). We predicted that an overshadowing effect would be observed in the food allergist task. However, given the heterogeneity in previous literature (e.g., [13,42]) regarding the relationship between overshadowing and schizotypy, we undertook exploratory analyses to examine the relationship between schizotypy dimensions and overshadowing. Additionally, we also sought to assess the nature of any overshadowing effect observed, which is not typically reported in overshadowing studies (e.g., [13,42]). That is, whether a unilateral overshadowing effect is observed - where only one element of a cue compound is learned about less well than an elemental cue; or whether reciprocal overshadowing is observed - where both elements of a cue compound are learned about less well than an elemental cue. This final comparison is of interest as the nature of the overshadowing effect is one method for distinguishing an attentional account of overshadowing (e.g., [32]) from a non-attentional account (e.g., [46]), with the former model predicting unilateral overshadowing, and the latter model predicting reciprocal overshadowing.

1. Method

1.1. Participants

A total of 276 participants were recruited from Swansea University's School of Psychology using the School's Participant Pool and the local community. There were 201 females, 73 males and 2 non-binary participants. Participants ranged from 18 to 66 years of age ($M = 22.30$; $SD = 6.59$). Participants received Participant Pool credits for their participation. Data collection commenced on 11th May 2021 and was completed on 9th February 2022. Ethical approval was provided by Swansea University's School of Psychology Ethics Committee. The sample size was based on an a priori power calculation using G*Power 3.1 [9]. To detect a small to medium overshadowing effect (Cohen's $d = 0.35$) with one within-subjects measurement (taken during the test stage), $\alpha = 0.05$ and Power $(1 - \beta) = .80$, results indicated a total of 52 participants would be needed. To detect a small to medium effect size of the schizotypy sub-scales on overshadowing (Cohen's $f^2 = .10$), with an alpha (α) of.05 and Power $(1 - \beta)$ of.80, results indicated that 199 participants would be needed using a multiple regression with 4 predictors and a single coefficient.

1.2. Stimuli and materials

Gorilla Experiment Builder [1] was used to administer the task and questionnaire online. Participants could use a desktop computer, a

laptop, or a tablet / mobile phone to access the study.

1.2.1. Overshadowing task

The experimental design can be seen in Table 1. In a training stage, participants were tasked with learning associations between foods (A – F) which served as cues, and reactions which served as outcomes (O1 and O2) in a fictitious patient ("Mr. X"). The foods were either presented in compound form (i.e., AB, CD) or elemental form (i.e., E, F). The foods and reactions were assigned to the letters and outcomes in Table 1 using a Latin-Square counterbalancing technique. There were six pictures of foods which served as cues A-F. These were: broccoli, cauliflower, mushroom, pepper, potato and tomato. The two reactions were presented individually in text form and served as O1 and O2. These were: "DIARRHOEA" and "VOMITING".

In the training stage, participants were presented with either a single food in the centre of the screen (i.e., an elemental trial), or two foods to the left and right of the centre of the screen (i.e., a compound trial), against a white background. The position of the foods on the screen (i.e., left or right of centre) was counterbalanced across trials. On both sets of trials two buttons containing the individual reaction options were presented at the bottom of the screen (e.g., "DIARRHOEA" and "VOMITING"). Each of these reactions was presented in capitalised white Arial text (font size: 16) against a small black background which represented a button participants could select. The position of these buttons was also counterbalanced across trials. Participants could only select one of the two buttons.

In the test stage, participants were asked to rate how likely each food was to cause each of the reactions. The cues (i.e., foods) were presented individually toward the left of the screen and the two reactions were positioned on the right of the screen (see Fig. 1 for example). Participants made their ratings for each reaction by moving a cursor on a Likert scale which ranged from 0 to 10 ['0′ = 'Very unlikely", '10′ = Very likely"] that was positioned next to each of the reactions.

1.2.2. Oxford-Liverpool Inventory of feelings and experiences (short version)

The short version of the Oxford-Liverpool Inventory of Feelings and Experiences (sO-LIFE; [35]) is a 43-item questionnaire designed to measure different four different components of schizotypy: Cognitive disorganisation, (e.g., "Do you often have difficulties in controlling your thoughts?"); Impulsive non-conformity (e.g., "Do you ever have the urge to break or smash things?"); Introvertive Anhedonia (e.g., "Are you much too independent to get involved with other people?"); and Unusual experiences (e.g., "Have you ever thought that you had special almost magical powers?"). Participants' responses are recorded in a binary Yes/No format. The sO-LIFE is a validated scale which has sound psychometric properties [10,35]. The Cronbach alphas for each of the subscales in this study were broadly in line with those of Mason et al. [35]: Cognitive disorganisation: $\alpha = 0.81$; Impulsive non-conformity: $\alpha = 0.61$; Introvertive Anhedonia: $\alpha = 0.56$; Unusual experiences: $\alpha = 0.71$.

Table 1
Design of Experiment.

	Training	Test
Overshadowing	AB – O1	A: O1- O2
	CD – O2	B: O1- O2
Control	E – O1	C: O1- O2
	F – O2	D: O1- O2
	-	E: O1- O2
	-	F: O1- O2

Note. A – F refer to foods (i.e., cues), whilst O1 – O2 refer to outcomes. AB and CD cues represent the overshadowing stimuli, whilst E and F represent the control stimuli.

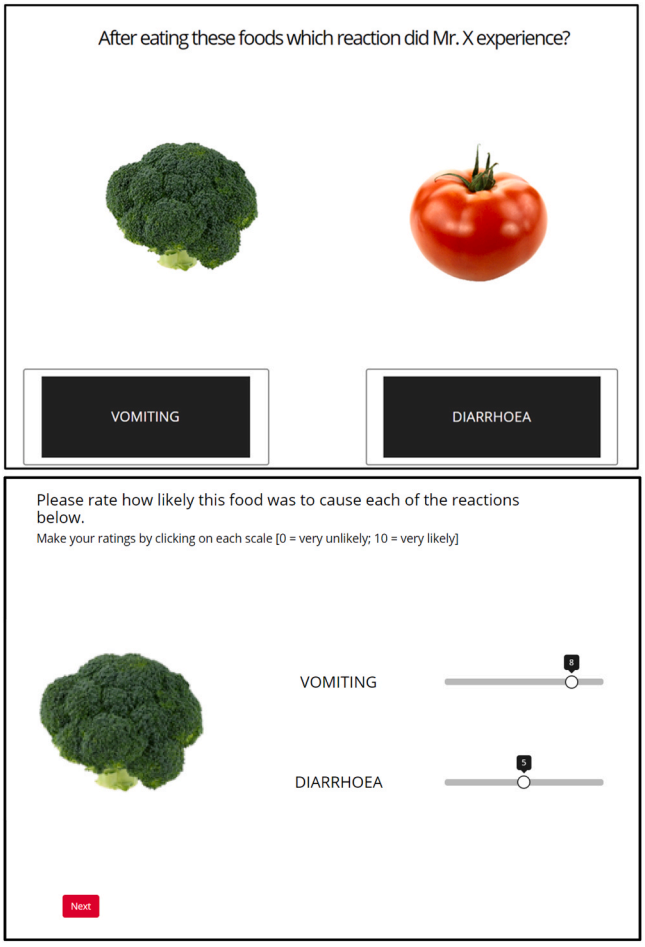

Fig. 1. – Example of a compound trial from the training stage (top) and an example trial from the test stage (bottom).

1.3. Procedure

Participants were sent an online link that took them to an information sheet and consent form, before providing demographic details (i.e., age and gender). Once demographic details had been provided, they were then presented with the following instructions before progressing to the training stage:

> *"In this experiment we would like you to imagine that you are an allergist (i.e., someone who tries to discover the cause of allergic reactions). You have just been presented with a new patient who suffers from different types of allergic reactions as a result of eating certain foods. In an attempt to discover which foods cause the different types of allergic reaction in Mr. X, you arrange for him to eat a number of different foods and observe the type of allergic reaction he suffers.*
>
> *On the following screens, you will be shown the foods Mr. X has eaten, and you will be asked to predict what type of allergic reaction he will suffer as a result of eating each meal. Each allergic reaction will be presented at the bottom of the screen. Make your prediction by selecting one of the allergic reactions below each of the foods. You will then be provided with feedback about what reaction Mr. X experienced. You will have to guess at first, but with the aid of the feedback your predictions should soon start to become more accurate."*

In the *training stage* participants were exposed to 2 blocks of 16 trials. The order of trials was block randomised with no break between blocks. Participants received 4 of each cue – outcome pairing (AB – O1, CD – O2, E – O1, F – O2) within each block. On each trial, at the top of the screen,

participants were presented with the following question above the food/s presented: "*After eating these foods which reaction did Mr. X experience?*". Participants were then required to make a response by selecting one of two buttons, positioned beneath the foods, containing each of the reactions. Upon selecting one of the reactions, they were presented with feedback about the reaction Mr. X had experienced. On this feedback screen, participants were presented with the following text: "After eating these foods *Mr X. experienced:*". The food/s Mr. X had eaten and the reaction Mr. X experienced were then presented. Each trial only ended once participants had made their response and the feedback screen had been presented. The feedback screen was presented for 1.5 s, before the next trial began. When all 32 trials were complete, participants proceeded to the test stage.

During the *test stage*, participants were presented with the following text at the top of each screen: "*Please rate how likely this food was to cause each of the reactions below. Make your ratings by clicking on each scale [0 = very unlikely; 10 = very likely].*" Beneath this text, each of the cues (i.e., foods) were presented individually, one per screen (see Fig. 1). Alongside each food (to the right), two Likert rating-scales were presented, one for each reaction. Participants were then required to make a rating for each of the reactions. Once they had provided ratings for each cue's likelihood of producing a reaction, they were presented with a screen informing them that they would now be asked to complete a short questionnaire. The 43-items of the sO-LIFE were then presented (one question per screen). Once participants had completed all questions, they were then presented with a debrief form.

1.4. Data analysis

Analyses were performed using JASP version 14.1 [30]. The dataset can be found on the Open Science Framework (https://osf.io/gxka4/?view_only=7b96b6cf04ac4011a82887e6c2098192). For all analyses an alpha (α) of .05 was adopted unless otherwise stated. Data were analysed using repeated measures analyses of variance (ANOVA), paired samples t-tests and simple and multiple regressions. For all ANOVAs, when the assumption of sphericity was not met, Greenhouse-Geisser corrected *F*-ratios and degrees of freedom are reported. Bayesian analyses were also undertaken, using default priors to estimate the Bayes Factor$_{10}$ (BF_{10}; [47]). As such, the weight of evidence for the alternative hypothesis over the null (BF_{10}) was examined, thus values > 1, < 1, and $= 1$, respectively represent increasing evidence for the alternative hypothesis, increasing evidence for the null hypothesis, and evidence for neither hypothesis [28].

2. Results

2.1. Training stage

To ensure that participants had learned the cue-outcome associations in the training stage we imposed a learning criterion of 60% across all training trials. This criterion, which is consistent with previous studies (e.g., [25,27]), resulted in 20 participants being excluded leaving 256 participants for all subsequent analyses.[1] As can be seen in Fig. 2, participants' mean proportion of correct responses for the compound (AB-O1 and CD-O2) and elemental stimuli (E-O1 and F-O2) were comparable across training trials, with learning approaching asymptote by the end of training. To analyse these data, a 2 × 8 repeated measures Analysis of Variance (ANOVA) was performed that compared stimulus type (Compound vs Elemental) and trial (1 – 8) as within-subjects variables. A main effect of trial was observed, F (5.14, 1310.81) $= 185.58$, $p < .001$, $\eta_p^2 = .42$, $BF_{10} > 100$. However, there was no effect of stimulus, $F(1, 255) = 0.55$, $p = .46$, $\eta_p^2 = .00$, $BF_{10} = 0.05$, or stimulus × trial interaction, F (5.20, 1327.06) $= 1.36$, $p = .23$, $\eta_p^2 = .01$, $BF_{10} < 0.001$.

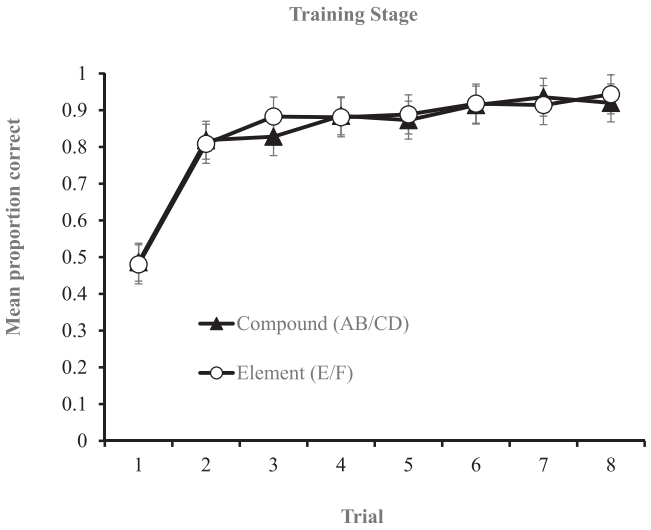

Fig. 2. – Mean proportion correct responses for compound (AB/CD) and element stimuli (E/F) during the training stage. Error bars represent SEM.

2.2. Test stage – overshadowing

To determine the extent to which participants' learning reflected the specific cue-outcome relationships difference scores were calculated for each cue for each participant. For example, participants ratings for stimulus A and O2 (i.e., the outcome that A was not paired with) were subtracted from their ratings for A – O1 (i.e., the outcome that A was paired with). This provides an outcome specific measure of the ratings provided for each of the cues and is consistent with methods for measuring causal learning present in previous literature (see: [27,25,44,45]). Fig. 3 illustrates the mean of participants' outcome specific ratings for the compound cues (A – O1, B – O1, C – O2 and D – O2) and the

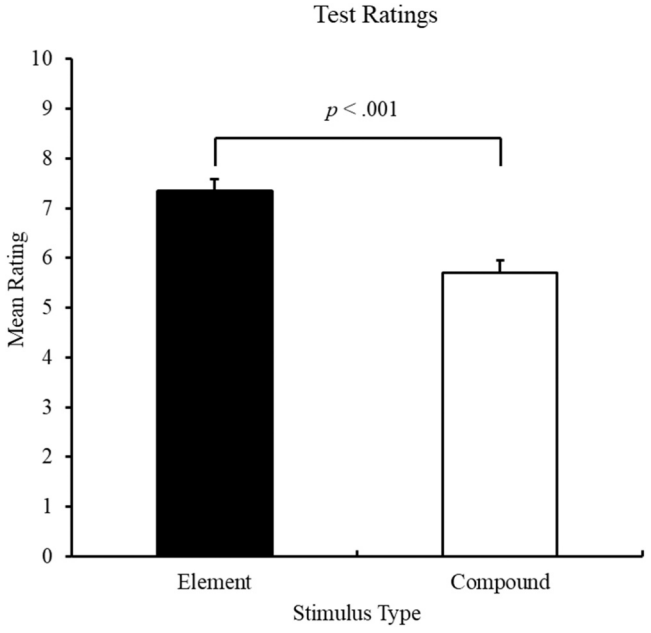

Fig. 3. – Mean ratings for compound (AB/CD) and elemental stimuli (E/F) during the test stage. Error bars represent SEM.

[1] The remaining participants age ranged from 18 to 66 years of age (M = 21.85; SD = 5.49). There were 189 females, 66 males and 1 non-binary participant. Excluded participants' data did not differ from included participants on any of the schizotypy subscales ($p > .05$).

elemental cues (E – O1 and F – O2) at test. A paired samples t-test of outcome-specific ratings for the elemental stimuli and the compound stimuli revealed a significant difference between these ratings, with higher ratings being provided for the elemental cues than the compound cues, t (255) = 6.19, p = <0.001, d = 0.39, BF_{10} > 100. These results therefore reveal an overshadowing effect.

To examine the nature of the overshadowing effect (i.e., whether the effect was reciprocal or unilateral) analysis was conducted on participants' ratings to the elements of the compound (e.g., A – O1 and B – O1) relative to their ratings for the elemental stimuli (i.e., E – O1 and F – O2). For each participant, the element of the cue compound that received the higher rating was rendered the "Overshadowing" stimulus (e.g., A – O1), whilst the element of the compound that received the lower rating was rendered the "Overshadowed" stimulus (e.g., B – O1). Outcome specific measures were then calculated in keeping with the previous analysis of the test data. The mean ratings for each stimulus type can be seen in Fig. 4. A one-way repeated measures ANOVA revealed a main effect of stimulus type (elemental, overshadowing, overshadowed), F (1.62, 413.21) = 65.46, p < .001, η_p^2 = .20, BF_{10} > 100. Bonferroni-corrected post-hoc tests revealed that the overshadowing stimulus was rated higher than the overshadowed stimulus, t (255) = 10.19, p < .001, d = 0.64, BF_{10} > 100. The elemental stimulus was also rated higher than the overshadowed stimulus, t(255) = 8.59, p < .001, d = 0.54, BF_{10} > 100. However, the elemental and overshadowing stimulus received comparable ratings, t(255) = 1.40, p = .488, d = 0.09, BF_{10} = 0.18, thus revealing a unilateral overshadowing effect.

2.3. Test stage: schizotypy and overshadowing

Table 2 displays mean scores (and standard deviations) for each of the subscales of the sO-LIFE, the size of the overshadowing effect (i.e., the difference between the compound and the element per participant), the difference (-) between the element and the overshadowing stimuli, the difference between the element and the overshadowed stimuli and the difference between the overshadowing and overshadowed stimuli. The Pearson correlation coefficients between all these measures are also provided.

To examine whether scores on each of the schizotypy subscales could predict overshadowing a standard multiple regression (using the "enter" method) was performed with scores on each of the schizotypy subscales as predictors and the size of the overshadowing effect for each participant as the outcome (i.e., the difference between the compound and the element per participant). [2] The regression model was not significant, F (4, 251) = 1.07, p = .37, adjusted R^2 = .00, BF_{10} = 0.02, and each of the predictors were also non-significant: cognitive disorganization (β = 0.10, p = .23); impulsive non-conformity (β = −0.02, p = .77); introvertive anhedonia (β = 0.09, p = .20) and unusual experiences (β = −0.06, p = .45). A simple linear regression was also performed to assess whether overall schizotypy scores (i.e., participants' sum score on the sO-LIFE) predicted the size of the overshadowing effect, the model was not significant, F (1, 254) = 1.13, p = .29, adjusted R^2 = .00, BF_{10} = 0.23.[3]

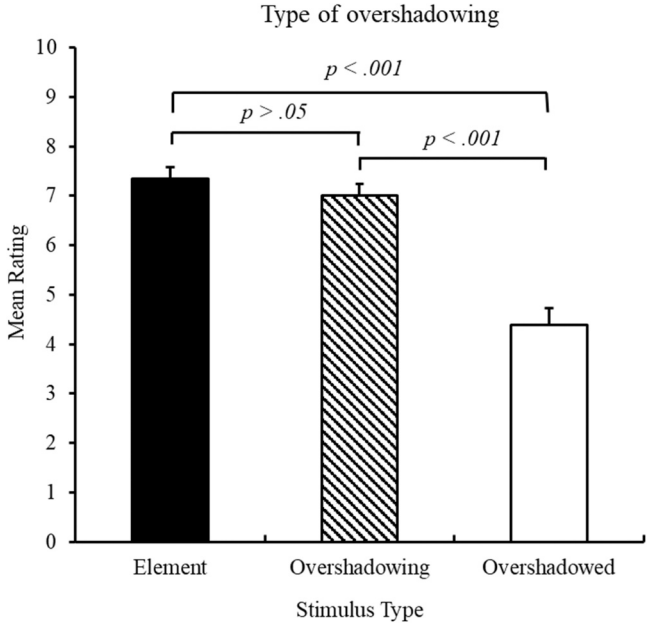

Fig. 4. – Mean ratings for the elemental stimuli (E/F) and the overshadowing and overshadowed stimuli during the test stage. Error bars represent SEM.

The difference in ratings between the element and the *overshadowed* stimulus was also not predicted by scores on the schizotypy subscales: F (4, 251) = 1.22, p = .31, adjusted R^2 = .00, BF_{10} = 0.02 (cognitive disorganization [β = 0.08, p = .35]; impulsive non-conformity [β = −0.01, p = .92]; introvertive anhedonia [β = 0.11, p = .10] and unusual experiences [β = −0.07, p = .39].

Differences in ratings between the element and the *overshadowing* stimulus were also not predicted by scores on the schizotypy subscales: F (4, 251) = 0.66, p = .62, adjusted R^2 = .01, BF_{10} = 0.00 (cognitive disorganization [β = 0.11, p = .18]; impulsive non-conformity [β = −0.04, p = .61]; introvertive anhedonia [β = 0.03, p = .63] and unusual experiences [β = −0.03, p = .67].

Finally, the schizotypy subscales did not predict a difference between ratings for the overshadowed and the overshadowing stimulus: F (4, 251) = 0.89, p = .47, adjusted R^2 = .00, BF_{10} = 0.01 (cognitive disorganization [β = 0.00, p = .99]; impulsive non-conformity [β = 0.02, p = .75]; introvertive anhedonia [β = 0.12, p = .08] and unusual experiences [β = −0.06, p = .44].

3. General discussion

The current experiment examined whether dimensions of schizotypy predicted the degree of overshadowing in a commonly used associative learning task to assess cue interaction effects. A small-to-medium sized overall overshadowing effect, and a medium-to-large sized unilateral overshadowing effect were observed in our data, the latter of which provides support for Mackintosh's [32] attentional account of overshadowing. However, none of the dimensions of schizotypy were associated with or predicted these effects. To our knowledge, these findings are the first to assess this relationship using an appropriately powered sample and to explore the nature of the overshadowing effect.

Previous studies have demonstrated that cue competition effects that are similar to overshadowing (e.g., blocking) have been associated with specific dimensions of schizotypy (e.g., [16,36]). However, studies specifically exploring the relationship between overshadowing and schizotypy have produced heterogenous findings. For instance, Granger et al. [13] reported a negative correlation between overshadowing and scores on the "unusual experiences" subscale of the O-LIFE. However, Pickett et al. [42] did not observe any relationship between overshadowing and schizotypy. In both cases, however, the sample sizes were relatively small (N < 70) for the analyses conducted which may have impacted the results. Indeed, underpowered studies can lead to false positives where statistically significant effects are detected, but

[2] We also performed all regression models we report with age and sex (dummy coded) as predictors. All regression models remained non-significant and age and sex were non-significant individual predictors.

[3] To examine any potential differences between extreme scorers, we also quartile split the data for the sO-LIFE subscales and the sum score and conducted a series of independent samples t-tests comparing overshadowing between the 0–25 percentile groups and 75–100 percentile groups. All t-tests were non-significant (smallest p = .08; BF_{10} =0.77).

Table 2

Mean scores (standard deviations) for the sO-LIFE subscales, the size of the overshadowing effect, and the mean difference (-) between the element and the overshadowing stimuli, the element and the overshadowed stimuli and the overshadowing and overshadowed stimuli. It also shows the Pearson correlation coefficients between these measures.

Measure	Mean (SD)	1	2	3	4	5	6	7	8
Cognitive disorganisation (1)	6.52 (3.06)	-	0.49 * **	0.36 * **	0.51 * **	0.09	0.09	0.08	0.02
Impulsive non-conformity (2)	3.63 (2.16)		-	0.16 *	0.48 * **	0.01	0.00	0.01	0.01
Introvertive Anhedonia (3)	2.70 (1.91)			-	0.24 * **	0.10	0.06	0.12	0.11
Unusual experiences (4)	4.43 (2.67)				-	0.00	0.01	-0.01	-0.02
Overshadowing size (5)	1.64 (4.24)					-	0.87 * **	0.94 * **	0.46 * **
Element–Overshadowing (6)	0.33 (3.77)						-	0.66 * **	-0.03
Element–Overshadowed (7)	2.95 (5.50)							-	0.73 * **
Overshadowing–Overshadowed (8)	2.62 (4.12)								-

Note. * denotes statistical significance < 0.05; * * denotes statistical significance < 0.01; * ** denotes statistical significance < 0.001

which are unlikely to reflect a true effect, leading to overestimates of effect sizes and low reproducibility [11,2]. The findings of the current study though are consistent with Pickett et al. [42] and Haselgrove and Evans [16]. Whilst Haselgrove and Evans reported a negative correlation between blocking and the introvertive anhedonia dimension of schizotypy, no such relationship was observed between overshadowing and schizotypy.

Taken together the results of our study, in conjunction with previous studies mentioned above, suggest that schizotypy dimensions may impact only some types of cue interaction effects (i.e., blocking), and not others (i.e., overshadowing). Interestingly, studies involving schizophrenia patients which have included overshadowing conditions have also suggested that overshadowing is not impacted by schizophrenia [19]. This is surprising given that many associative learning models (e.g., [46,41,32]) assume that cue interaction effects such as blocking and overshadowing are different manifestations of a more general, competitive learning, principle in which associative strength acquired by one stimulus restricts the acquisition of associative strength that can be acquired by another, co-present stimulus. The crucial difference between blocking and overshadowing is the procedural arrangement between the stimuli. In a blocking study, a two-stage learning process is typically employed whereby the blocking cue is first presented to participants prior to being presented in compound with a novel cue. In an overshadowing study elemental and compound stimuli are typically presented in a single stage of training. It is possible that these differences in experimental procedures could account for the differential impact of schizotypy on these effects. For example, in a blocking study cue competition occurs because learning about the blocked stimulus is limited by learning about the blocking stimulus that has (predominantly we assume) occurred in an *earlier* stage of the experiment. In overshadowing, however, cue competition arises between the overshadowing and overshadowed stimulus at a time when the two stimuli are (potentially) acquiring associative strength. It is conceivable that schizotypy is sensitive to differences in the way in which associative strength that has been acquired in the past interacts with more recently acquired associative strength. Furthermore, in the context of a blocking study, it is possible that the aberrant salience of the novel cues presented during Stage 2 is particularly high due to the to their relative novelty to the blocking cues that are also presented in the first stage of training. This could therefore result in these stimuli having higher associability and being learned about better – this would go some way to explaining the counterintuitive results of Jones et al. (1992) whereby the blocked cue was learned about better than a control. In an overshadowing study, however, all stimuli are typically presented in a single stage of training. Therefore, preventing elements of the compound from having differential aberrant salience through variations in previous exposure to the stimuli.

It is worth noting, however, that similar heterogeneous findings have been observed in relation to blocking and schizotypy. For instance, Haselgrove and Evans [16] and Moran et al. [36] demonstrated associations between blocking and specific schizotypy dimensions. However, Humpston et al. [17] did not observe an association between blocking and any schizotypy dimensions. This could possibly be due to variations in samples and the extent to which schizotypal traits were present. Additionally, the sample sizes used may have also resulted in heterogeneous findings. Future research should seek to further examine the association between schizotypy and cue competition effects using high powered samples to understand the extent of the association between schizotypy and cue interaction effects. Understanding the true extent of an association between these effects and the dimensions of schizotypy is important as performance on cue interaction tasks has the potential to serve as a clinical marker for schizophrenia if there is indeed an association between the two [36].

There are limitations to the current study though. For example, in the current study the short version of the OLIFE was administered as a measure of schizotypy. However, in Granger et al. [13] a longer 104 item version of the OLIFE was used which has more robust psychometric properties [34]. This could possibly account for the different results. That said, Haselgrove and Evans [16] also used the same 104-item version of the OLIFE and did not find an association with overshadowing. Interestingly, Pickett et al. [42] also failed to observe an overshadowing effect using the food allergist task and noted issues with the validity of the task given participants' potential pre-conceived ideas about certain foods potential to produce illness. However, not using foods which are commonly associated with adverse reactions (e.g., chicken, eggs) as stimuli and counterbalancing or randomisation of stimuli should circumvent these issues. In the current study only fruits and vegetables were used as stimuli and all foods and outcomes were counterbalanced. Moreover, this paradigm is the most used to assess cue interaction effects and did not prevent an overshadowing effect being observed in the current study. As is common with psychology studies the sample also largely consisted of females who have been observed to show cue interaction effects to a greater extent than males [7]. However, an independent samples t-test revealed that participants' sex did not influence overshadowing in our study ($t = 0.20$, $p = .84$, $BF_{10} = 0.16$). Our sample being largely young female university students does limit the generality of our findings though. Previous patient studies have typically had a greater number of males than females and have been conducted in-person [36] as opposed to the online testing method we employed. In our study we also did not capture details about whether participants had a diagnosis or family history of psychiatric disorders or drug abuse. The demographics of our sample and testing method (i.e., online) could therefore account for differences between our results and previous studies findings. It should be noted, however, that both Granger et al. [13] and Pickett et al. [42] also had largely student samples and online conditioning studies have been demonstrated to be as valid and reliable as laboratory-based studies [3,4].

Future research should therefore seek to include a more balanced sample to improve generalisability and administer a range of schizotypy measures (e.g., the long and short O-LIFE) to establish if the scale used is impacting on results. Trait measures of anxiety which have also been associated with the dimensions of schizotypy [29] could also be administered to examine the relationship between overshadowing, schizotypy and anxiety. It would also be prudent to embed a range of cue

competition designs in one experimental paradigm in a similar manner to Haselgrove and Evans [16] to assess if and why schizotypy may impact certain cue interaction effects (e.g., blocking) but not others (e.g., overshadowing). Incorporating eye-tracking methods to assess participants gaze patterns during completion of these tasks would also provide an overt measure of attention in addition to participants ratings data.

In conclusion, the current study examined whether there was a relationship between overshadowing and the different dimensions of schizotypy. Whilst a unilateral overshadowing effect was observed, the different dimensions of schizotypy did not predict this overshadowing effect. These results question the extent to which schizotypy influences overshadowing and potentially other cue competition effects.

CRediT authorship contribution statement

Martyn Quigley: Conceptualization, Methodology, Software, Data collection & Analysis, Writing – review & editing. **Alexander Bradley:** Analysis, Writing – review & editing. **Mark Haselgrove:** Conceptualization, Methodology, Analysis, Writing – review & editing.

Data Availability

Shared on OSF.

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