Autism tendencies and psychosis proneness interactively modulate saliency cost

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Abstract

Atypical responses to salient information are a candidate endophenotype for both autism and psychosis spectrum disorders. The present study investigated the costs and benefits of such atypicalities for saliency-based selection in a large cohort of neurotypical adults in whom both autism and psychosis expressions were assessed. Two experiments found that autism tendencies and psychosis proneness interactively modulate the cost incurred in the presence of a task-irrelevant salient distractor. Specifically, expressions of autism and psychosis had opposing effects on responses to salient information such that the benefits associated with high expressions for autism offset costs associated with high expressions for psychosis. The opposing influences observed on saliency cost may be driven by distinct attentional mechanisms that are differentially affected by expressions for autism and psychosis.

1. Introduction

In both clinical and non-clinical participants, expressions of autism and psychotic spectrum disorders (ASD and PSD, respectively) are associated with differences in attentional processing [1]. Although these are often seen as deficits, there is also some evidence of autism-related benefits on some tasks [2, 3]. As such, it is far from clear whether autism and psychosis expressions yield these effects for the same reasons, not least because it is uncommon for these expressions to be assessed in the same participants [4]. While ASD and PSD have been formally conceptualized as distinct disorders since the 1970s [5], recent theoretical and empirical evidence, however, highlights the need to assess both autism and psychosis expressions in tandem as they might be additive or even interact [6-8]. This is based on increasing evidence suggesting that ASD and PSD, and particularly schizophrenia, share multiple phenotypes (e.g. attentional and social functioning difficulties) and risk factors (e.g., genetic, neurodevelopmental) [7, 9, 10], and can co-occur at both the diagnostic and trait levels within the individual [11-13]. Here, we investigate the effect of autism traits and positive psychosis expressions on saliency-based selection in a large cohort of neurotypical adults. The assessment of positive psychotic expressions rather than the general construct of psychotic experiences (which includes both positive and negative symptoms) is based on evidence showing that autism traits and positive psychotic expressions constitute endpoints of a single continuum in the non-clinical population [14-16], and that negative symptoms do not reliably discriminate between ASD and PSD [17]. Salience-based selection is a key attentional mechanism associated with the ability to bias attention towards (or away from) salient information (Mevorach et al., 2006). Since atypical responses to salient information are considered a candidate

endophenotype for both ASD [18] and PSD [19], understanding how healthy variations in the expression of autism and psychosis affect attentional processing can facilitate our understanding of clinical autism and psychosis and their interaction.

Research in PSD and the broader spectrum of PSD expressions in healthy participants has consistently shown increased processing cost in the presence of salient distractor stimuli [15, 20-23]. For example, in a global-local processing paradigm where participants were required to judge whether a pair of compound stimuli (global forms composed of local forms) were identical or not, there was a significant slowing in participants with schizophrenia, particularly in the presence of a salient distractor at the local level [21]. Similarly, neurotypicals with high positive schizotypy scores had more difficulty filtering out the non-relevant salient stimulus (the more complex figure) when they were required to detect an embedded figure [15].

In contrast, research in ASD and the broader spectrum of ASD traits in neurotypical participants finds evidence of both positive and negative effects on the ability to ignore distracting salient information [3, 24, 25]. For example, compared to typically developing children, children with ASD have been shown to be more resistant to both non-social (e.g., oddballs) [2] and social (e.g., faces) distractors [3], and that the degree of interference produced by the distractor appears to negatively correlate with the severity of autistic traits [3]. Notably, there are also reports of negative effects of ASD on information processing in the presence of salient distractors [25-27]. For present purposes, the critical point is that while handling of salient information may be atypical in ASD, the effects are not necessarily negative.

The evidence described above opens the possibility that expressions of ASD and PSD might each have effects on salience processing. However, since ASD and PSD can co-occur at both the diagnostic and trait levels within the individual [4, 8, 11], it is important to determine the relative impact of disorder-specific expressions on phenotypes within an individual. This question has significant implications for the individual's treatment and prognosis, as well as the nature of the relationship between ASD and PSD. Despite evidence of saliency-related effects in both ASD and PSD, no previous studies of salience effects have directly compared the two conditions, or the effect of their co-occurrence at either the trait or diagnostic levels.

One approach to evaluating the effect of ASD-PSD co-occurrence on the suppression (or filtering) of salient information is by examining the association of psychosis proneness and autistic tendencies among non-clinical populations. This approach draws on the notion that both autistic [28] and psychotic tendencies [29-31] exist on a continuum, ranging from typicality to disorder, and has the advantage of eliminating the confounding effects of active symptomatology, medication or chronicity [31]. We therefore investigated the effect of autistic tendencies and psychosis proneness on the cost associated with the processing of information in the presence of competing salient information in a large sample of non-clinical adults. More specifically, we examined how autistic and psychotic tendencies affected the processing of two competing sources of information where one set of information was more prominent (i.e., more readily available for processing) but irrelevant and the other was relevant but less prominent.

To this end, saliency was examined in two separate experiments. The first was Mevorach et al.'s (2009) variant of Navon's classic global-local task [32], and the second was a novel Face-Scene Perception Task. The first task assesses overall local and global biases, selective attention and saliency suppression in the context of compound letters (see Method). The second task expands on the first in that it also enabled us to test for attentional/perceptual biases to socially relevant stimuli (i.e., faces) as well as whether the effects were perceptual or attentional, which is made possible by the inclusion of neutral displays that do not require attention selection or filtering. In addition, the use of two tasks allows us to assess the generalizability of the effects of autism tendencies and psychosis proneness on the suppression/filtering of competing salient information. Autistic tendencies and positive psychotic experiences were respectively assessed with the Autism Spectrum Quotient [28] and the Community Assessment of Psychic Experiences Questionnaire [33]. These are well-validated questionnaires that have been used extensively in the general population. While the focus of the current study was on saliency, we also tested for the effect of autism and psychosis traits on differences in information processing as a function of level (i.e., local versus global), target (face versus scene) and congruency (congruent versus incongruent information) given research suggesting that information processing related to these factors also varies in both autism and psychosis [15, 34, 35].

Based on findings from existing literature, we predicted that higher levels of psychosis proneness would increase the burden of information processing in the presence of salient distracting stimuli. While the literature regarding the affect of autism traits is less clear, we

further predicted that any increased cost associated with autism tendencies would vary depending on the level of co-occurring psychosis proneness, and thus may help resolve some of the discrepancy within autism research. The effect of their co-occurrence would lead to one of the following effects: (1) co-occurrence would result in a non-additive effect perhaps due to a ceiling effect, or a dominance effect where the effect is mainly driven by level of psychosis, (2) co-occurrence would result in an additive effect leading to greater interference by the competing salient distractor, or (3) co-occurrence would result in a sub-additive effect where the cost would be reduced in the presence of both conditions, perhaps through some cancelling out effect, whereby saliency suppression is contrastingly modulated by autism and psychosis tendencies. The latter scenario is conceivable if traits for autism and psychosis have opposite effects on distraction by salient but irrelevant information [3, 15, 20], and would be consistent with the suggestion that ASD and PSD exert diametric effects on cognition and behavior [16].

2. Method

2.1. Participants

Data were collected from 202 healthy university students (43 males, 159 females; mean age = 21.45, SD = 4.33). Participants self-reported that they have no history of psychiatric illness, epilepsy, neurological disorders, or brain injury, current or past alcohol and/or substance abuse problems. The University of Birmingham Research Ethics Committee approved the study, and written informed consent was obtained from all participants.

2.2. Measures and materials

Psychosis proneness was assessed using with 20-item positive scale of the *Community Assessment of Psychic Experiences (CAPEp) questionnaire* [33], and autism tendencies were assessed using the *Autism Spectrum Quotient (AQ)* [28]. The internal consistency in this study of CAPEp (Cronbach's α = .84) and AQ (Cronbach's α = .82) was very good. Both CAPEp and AQ have been, respectively, shown to be sensitive to the screening of individuals with first episode psychosis [36] and ASD [28], which undescores their sensitivity to the spectrum of expressions from typicality to disorder. Depressive symptomatology was assessed using *The Center for Epidemiologic Studies Depression Scale – Revised (CESD-R)* [37]. The internal consistency in this study is high (Cronbach's α =.91). Depressive symptoms are measured since they are frequent clinical features in both ASD [38] and PSD [39], and may affect performance on cognitive tasks [40]. Higher scores on AQ, CAPEp and CESD-R reflect higher levels of symptom expressions.

2.2.1 The Global-Local Task

In this task, participants were required to identify the global letter of the compound figure made up of small letters (an S or an H) or the local letter of the compound figure (an S or an H) while ignoring information on the other level. As can be seen from Figure 1A below, saliency was manipulated in two ways: Local saliency was achieved by using alternating colors for the local elements (to break grouping), and global saliency was achieved by blurring the local elements. As such, participants were asked to detect the local or the global letter under four conditions: identifying the global letter when the global level is more salient, identifying the global letter when the local level is more salient, identifying the local letter when the local level is more salient, and identifying the local letter when the global level is more salient. Participant

pressed one of two keys on the keyboard: 'K' and 'M', which were respectively labeled 'S' and 'H' (see Supplementary material for further details).

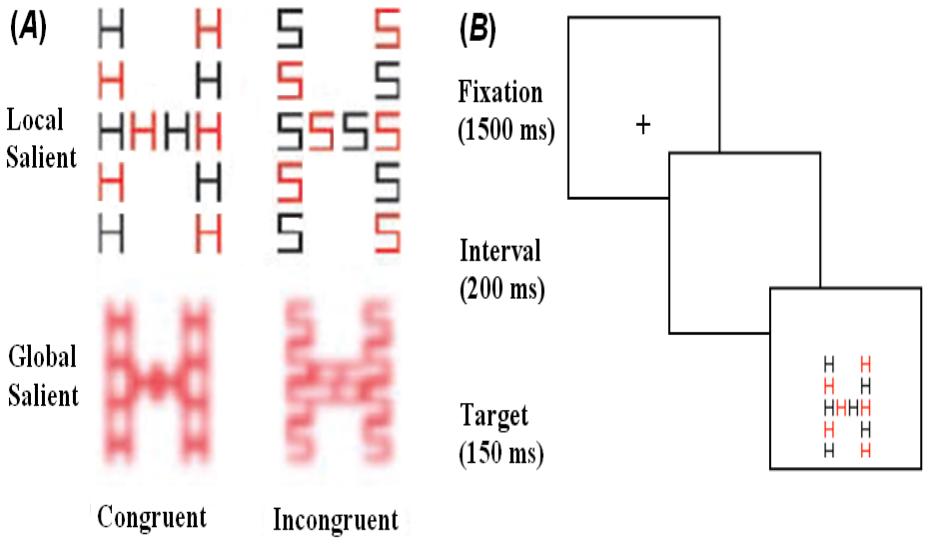

Figure 1. (A) Example of stimuli for the local-global task (Original stimuli were presented against a black background). (B) Typical trial display sequence.

2.2.2 The Face-Scene Perception Task

In this task, participants were required to either detect a face or a scene. To be consistent with the response keys from the Global-Local task, the two faces and two scenes were associated with the same response keys on the keyboard: 'K' and 'M', relabeled 'S' and 'H'. Accordingly, participants were required to associate the scene or the face with the corresponding letter (H or S) (see Figure 2A). A sheet depicting these associations was placed in front of the participant whilst performing the task, should the participant need a reminder as to which face/scene was associated with which letter. These faces and scenes were superimposed onto each other (Figure 2B) to manipulate saliency and congruency. In the neutral condition, the face (or the scene) was presented together with a scrambled version of the scene (or the face). The

superimposed combinations used a manipulation of the face or scene contrast at a 70%/30% ratio. Thus for more salient face displays, the face was presented at 70% contrast and the scene (or scrambled scene) was presented at 30% contrast. For more salient scene displays, these values were reversed. Congruency and incongruency were achieved by superimposing faces and scenes that were associated with the same letter (i.e., no response conflict) or different letters (i.e., response conflict), respectively (see Supplementary material for details).

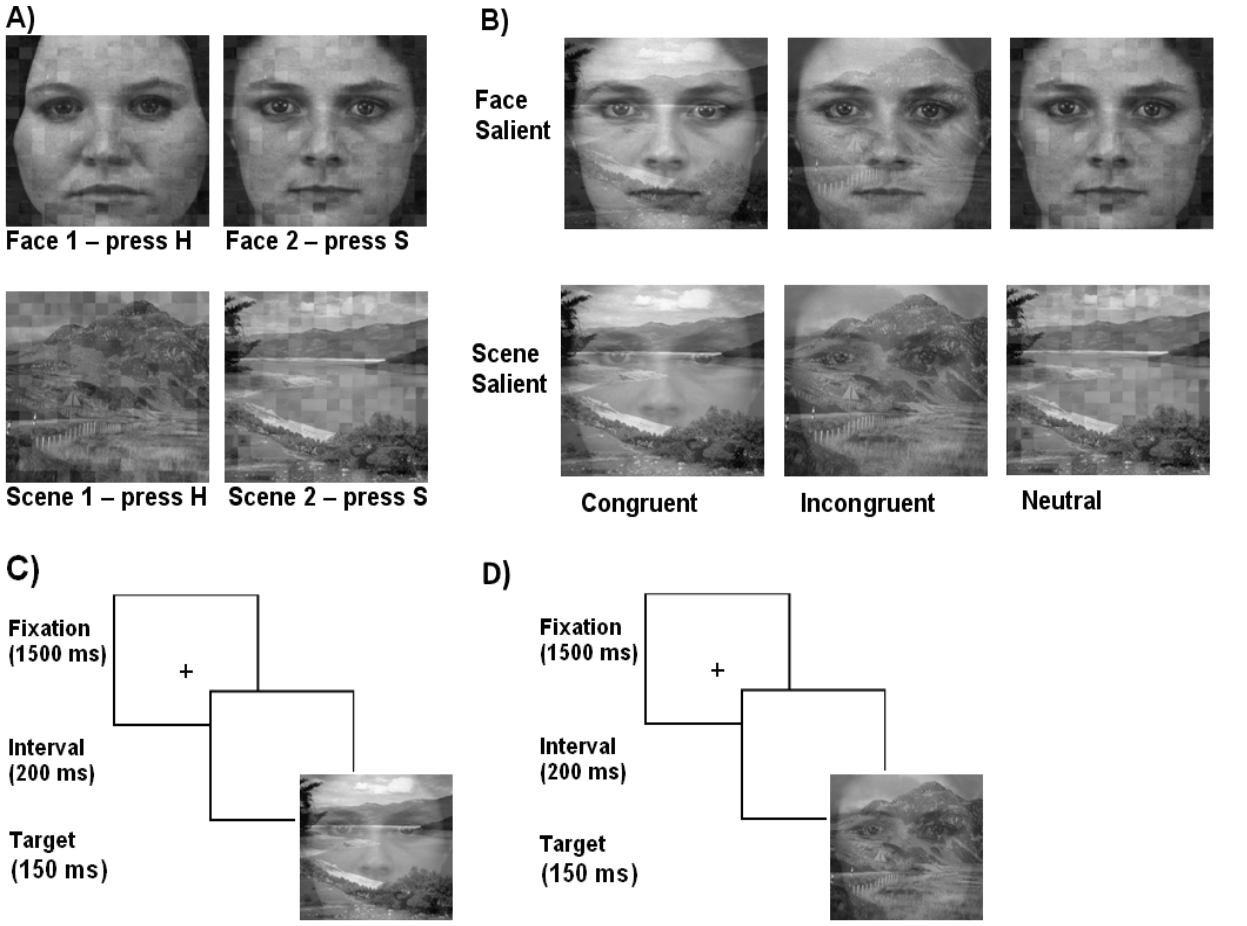

Figure 2. (A) Stimuli of the face-scene perception task. (B) Faces and scenes in salient/non-salient, congruent/incongruent and neutral conditions. (C) Typical trial display sequence for congruent stimuli, i.e., where the face and the scene are associated with the same letter (S-S; no response conflict). (D) Typical trial display sequence for incongruent stimuli, i.e., where the face and the scene are associated with different letters (S-H, response conflict).

2.3. Analytic Approach

For each task, we computed inverse efficiency scores (RT/Proportion correct) for each cell of the design for each participant. The use of efficiency scores, which is particularly recommended for tasks in which overall accuracy is over 80%, allows us to incorporate both RT and accuracy into a single measure [41], and to be consistent with previous studies using similar paradigms [42, 43]. In our study, overall accuracy was 96.5% in the Global-Local task, and 92.31% in the Face-Scene task. Overall performance on the Global-Local task as was assessed using a 2x2x2 repeated measures ANOVA with Level (global vs. local), Saliency (global salient vs. local salient) and Congruency (congruent vs. incongruent) as within subject factors. Overall performance on the Face-Scene task was assessed using 2x2x3 repeated measures ANOVA with Target (Face vs. Scene), saliency (face salient vs. scene salient) and Congruency (congruent vs. incongruent vs. neutral) as within subject factors.

Next, and to minimize the potential influence of outliers [44], we used Generalized Linear Models to assess the association of individual differences autism and positive psychotic expressions and their interaction on the cost associated with each factor in the Global-Local and Face-Scene tasks, namely saliency cost, level/target difference and congruency interference. In both tasks, *saliency cost* was computed as the difference in performance between conditions when the non-target is the salient aspect of the display (i.e., Distractor salient) and when the target is the salient aspect of the display (i.e., Target Salient) (i.e., Distractor Salient $_{\text{minus}}$ Target Salient). In the Global-Local task (Figure 1), *level difference* was computed as the difference between conditions when the target is presented at the local level and when the target is presented at

the global level (i.e., Local $_{minus}$ Global), and *congruency interference* as the difference between conditions when the target is incongruent with the other element of the display and conditions when the target is congruent with the other element of the display (i.e., Incongruent $_{minus}$ Congruent).

In the Face-Scene task (Figure 2), *target difference* was computed as the difference between conditions identifying faces and conditions identifying scenes (i.e., Face $_{minus}$ Scene), and *congruency interference* as the difference between conditions containing a response conflict between the target and the competing element of the display and conditions in which there is no response conflict (i.e., Incongruent / Neutral $_{minus}$ Congruent / Neutral). We also tested the effect of autism tendencies and psychosis proneness on performance in the *neutral-only* condition to see if they also explain simple effects of perception.

Where appropriate, group comparisons were conducted using t-tests, and correlation analyses were conducted using spearman's ρ.

3. Results

Two hundred and two participants completed both the Global-Local and the Face-Scene tasks. Due two data exclusion, the sample composition in both tasks differed slightly. Table 1 summarizes the sample characteristics in each of the two tasks.

Table 1. Sample characteristics in the Global-Local and Face-Scene Tasks

Task	Global-Local Task (N=196)*	Face-Scene Task (N=197)**
Gender (Male/Female)	41/155	42/155
Age	21.40±4.36	21.45±4.35
CAPEp	27.25±5.06	27.25±4.98
AQ	16.25±6.29	16.25±6.29
CESD-R	12.47±11.13	12.47±11.13

***** 6 participants were excluded. The data of one participant were excluded for a program failure and 5 additional for not following instructions, i.e., detecting global when the task was to detect local and vice versa.

****** 5 participants were removed from the analysis for failing to follow task instructions, i.e., responding to faces rather than to scenes or vice versa.

In both the Global-Local and Face-Scene tasks, significant Spearman's *ρ* correlations were observed between AQ and CAPEp (r=.31, p<.001; r=.32, p<.001), AQ and CESD-R (r=.38, p<.001; r=.38, p<.001), as well as between CESD-R and CAPEp (r=.36, p<.001; r=.38, p<.001). There were no associations between age and either AQ or CAPEp (-.07<*rs*<.07, all *ps*>.34; -.06<*rs*<.08, all *ps*>.26). Age was negatively correlated with CESD-R (r=-.16, p=.024; r=-.15, p=.036). There were no differences between male and female participants on any of these measures except for age where female (M±SD= 20.92±4.08; 20.94±4.08) were younger than male (M±SD= 23.22±4.93; 23.31±4.85) participants (t=2.76; p=.008; t=2.90; p=.005).

3.1. The Global-Local Task

Figure 3 shows the results of the 2x2x2 repeated measure ANOVA of the participants' performance on the task, suggesting that the presence of a salient distractor has a measurable effect on processing cost (See Supplementary material for complete analytic details).

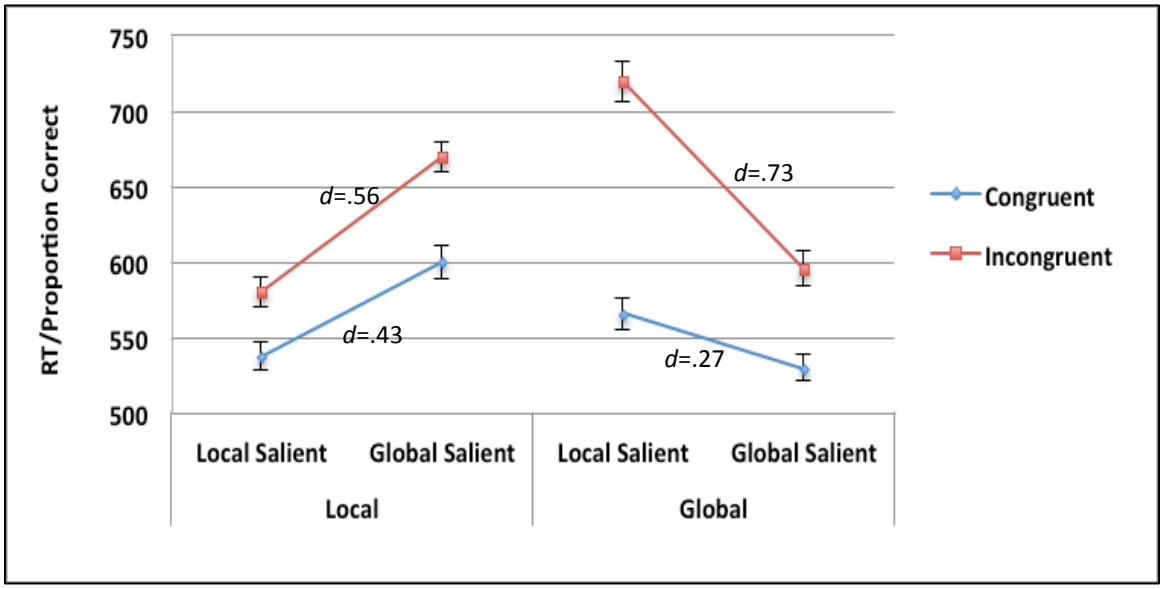

Figure 3. Overall performance on the Global-Local Task as a function of level (local vs. global), saliency (local salience vs. global saliency) and congruency (congruent vs. incongruent). Effect sizes (Cohen's *d*) represent the magnitude of the cost associated with the shift from target salient to distractor salient in the congruent and incongruent conditions (all *ps*<.001). Bars represent standard errors of the mean.

3.1.1. The effect of autism tendencies and psychosis proneness on level difference, congruency interference and saliency cost

First, Spearman's *ρ* indicated no correlations between age or CESD-R scores on any of the dependent variables (i.e., level difference, congruency interference and saliency cost) except for a negative association between age and congruency interference (r=-.17, p=.015). There were also no significant correlations among the dependent measures, or differences as a

function of gender. Each dependent measure was analyzed in separate regression models with the AQ scores, CAPEp scores and their interaction (AQ x CAPEp) as predictors. Since only age was associated with congruency interference, the model estimating congruency interference was carried out while also controlling for age [45]. The regression models for the level difference ($X^2_{(df=3)}$=2.59, p=.46) and congruency interference ($X^2_{(df=4)}$=3.44, p=.49) were non-significant. The model estimating saliency cost was significant ($X^2_{(df=3)}$, =11.03, p=.012; R^2=.055), with parameter estimates showing significant positive association between saliency cost and the CAPEp scores (β(±SE)=7.26(3.29), $X^2_{(df=1)}$=4.86, p=.027) and at a positive trend with the AQ scores (β(±SE)=8.34(4.50), $X^2_{(df=1)}$=3.43, p=.064). The interaction term of the AQ scores x CAPEp scores was negatively associated with saliency cost (β(±SE)= -.39(.17), $X^2_{(df=1)}$=5.35, p=.021). Importantly, the change in the variance explained by the model due to the inclusion of the interaction was significant (ΔR^2=.026; F=5.24, p=.023), or 47.27% of the total variance explained by the model.

To investigate the interaction, we first visualized the effect of one predictor on saliency cost at the participants' mean score, 1SD below the participants' mean score and 1SD above the participants' mean score of the other predictor using MODPROBE for SPSS [46], by plots of simple regression lines. Figure 4A visualizes the association between psychosis and saliency cost at low AQ (AQ=9.96), average AQ (AQ=16.25), and high AQ (AQ=22.54), and Figure 4B visualizes the association between autism tendencies and saliency cost at low CAPEp (CAPEp=22.19), average CAPEp (CAPEp=27.25), and high CAPEp (CAPEp=32.31). To identify the region/values of the moderator variable where the predictor has a significant effect on saliency cost, we used the

Johnson-Neyman method using MODPROBE for SPSS [46]. This method provides a 'high-resolution picture' of the interaction by estimating the value(s) of AQ, at which CAPEp (or vice versa) has a significant effect on saliency cost. This is established by identifying the precise value(s) along the continuum of the moderator for which the regression slopes of the predictor is estimated to be significantly different from zero. According to this analysis, increasing psychosis proneness (Figure 4A) is associated with significantly increasing saliency cost in individuals scoring below 9 on the AQ, but with significantly reduced cost in individuals scoring above 29 on the AQ. Conversely, increasing autism tendencies were only associated with a significant reduction in saliency costs in individuals scoring above 26 (average or high) on the CAPEp (Figure 4B).

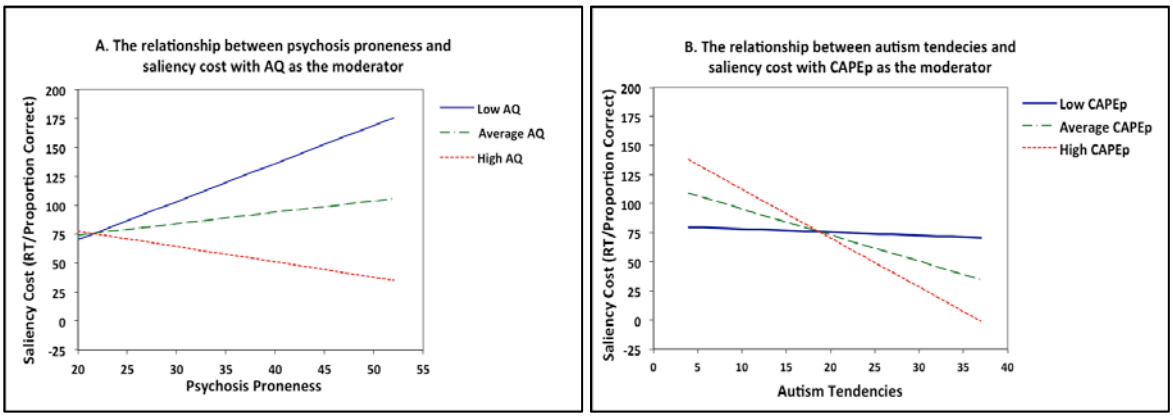

Figure 4. (A) Visualizes the association between psychosis proneness and saliency cost by plots of simple regression lines at low (-1 SD), average, and high (+1 SD) AQ scores as moderators. (B) Visualizes the association between autism tendencies and saliency cost by plots of simple regression lines at low (-1 SD), average, and high CAPEp scores (+1 SD) as moderators. Overall, saliency cost is increased with increasing psychosis proneness, except when the AQ scores are high (Figure 4A), and decreased with increasing autism tendencies, especially when the CAPEp scores are average and above (Figure 4B).

3.2. The Face-Scene Perception Task

Figure 5 shows the results of the 2x2x3 repeated measure ANOVA of the participants' performance on the task, suggesting that the presence of a salient distractor has a measurable effect on target identification (See Supplementary material for complete analytic details).

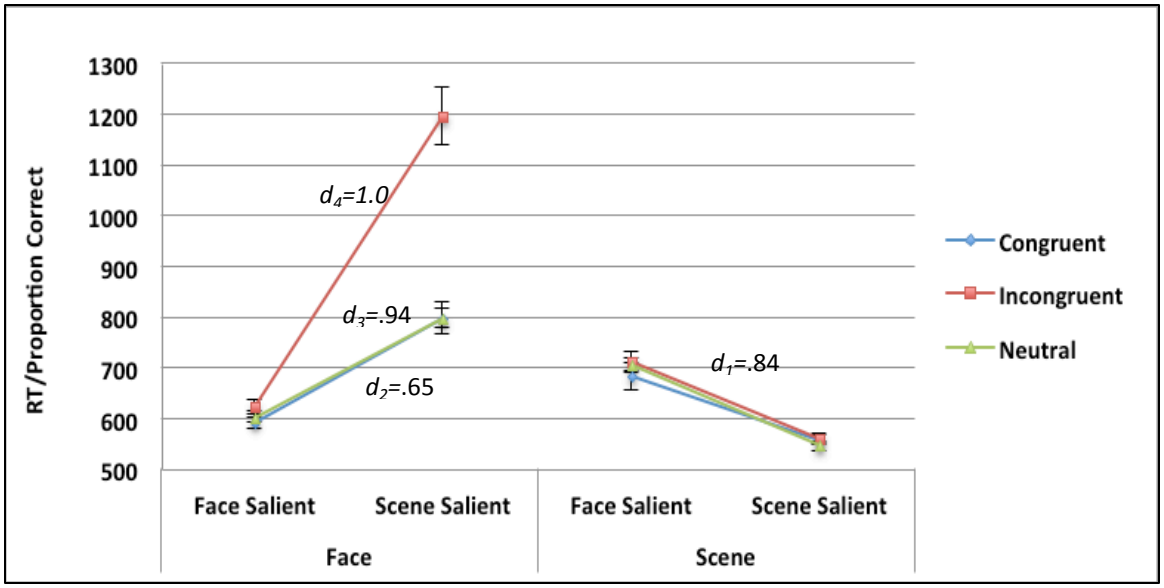

Figure 5. Overall performance on the Face-Scene Perception Task as a function of Target (Face vs. Scene), saliency (Face salient vs. Scene Salient) and congruency (Congruent vs. Incongruent vs. Neutral). Effect sizes (Cohen's *d*) represent the magnitude of the cost associated with the shift from target salient to distractor salient (all *ps*<.001). d_1 represents the overall effect size of saliency cost in the scene condition (no effect for congruency). In the face condition, d_2 and d_3 represent the effect sizes of saliency cost in the congruent and neutral conditions, respectively. d_4 represents the effect size of saliency cost in the incongruent condition. Bars represent standard errors of the mean.

3.2.1. The effect of autism tendencies and psychosis proneness on target difference, congruency interference and saliency cost

First, Spearman's ρ revealed no correlations between any of the dependent variables (i.e., target difference, congruency interference and saliency cost) with age or CESD-R scores. There

were also no differences between male or female participants on any of these measures. There were, however, significant associations between target difference and congruency interference (r=.24, p=.001), target difference and saliency cost (r=.50, p<.001), as well as congruency interference and saliency cost (r=.40 , p<.001). Accordingly, each dependent measure was entered into separate regression models with the AQ scores, CAPEp scores and their interaction (AQxCAPEp) as predictors, while controlling for the other two dependent measures. Since age, gender and CESD-R scores were not associated with any of the dependent measures, they were not included as covariates in the regression models [45].

The overall models for target difference (controlling for saliency cost and congruency interference) ($\chi^2_{(df=3)}$ =4.42, p=.22) and congruency interference (controlling for saliency cost and target difference) ($\chi^2_{(df=3)}$ =3.71, p=.30) were nonsignificant, suggesting that neither target selection nor the presence or absence of response conflict was affected by inter-individual differences on autism or psychosis. In contrast, the regression model estimating saliency cost (controlling for target difference and congruency interference) was significant ($\chi^2_{(df=3)}$ =18.94, p<.001, R^2=.092), with parameter estimates showing significant association between saliency cost and CAPEp scores (β(se)=23.47(9.97), $X^2_{(df=1)}$=10.56, p=.001) and at a trend with the AQ scores (β(se)=17.90(7.22), $X^2_{(df=1)}$=3.22, p=.073). The interaction term of AQ scores x CAPEp scores was also significant but negatively associated with saliency cost (β(se)=-.79(.37), $X^2_{(df=1)}$=4.52, p=.034). Importantly, the change in the variance explained by the model due to the inclusion of the interaction was significant (ΔR^2=.021; F=4.43, p=.037), or 22.8% of the total variance explained by the model.

We probed the interaction following the same analysis we applied in the Local-Global task. Figure 6A visualizes the interaction between psychosis and saliency cost by plots of simple regression lines at low AQ (AQ=9.95), average AQ (AQ=16.25), and high AQ (AQ=22.54), and Figure 6B visualizes the interaction between autism tendencies and saliency cost at low CAPEp (CAPEp=22.27), average CAPEp (CAPEp=27.25), and high CAPEp (CAPEp=32.23). According to the Johnson-Neyman method, increasing psychosis proneness was associated with significantly increased saliency cost (i.e., $p<.05$) only in individuals scoring below 23 (low or average) on the AQ (Figure 6A). Conversely, increasing autism tendencies were only associated with decreasing saliency costs in individuals scoring above 27 (average or high) on the CAPEp scale (Figure 6B).

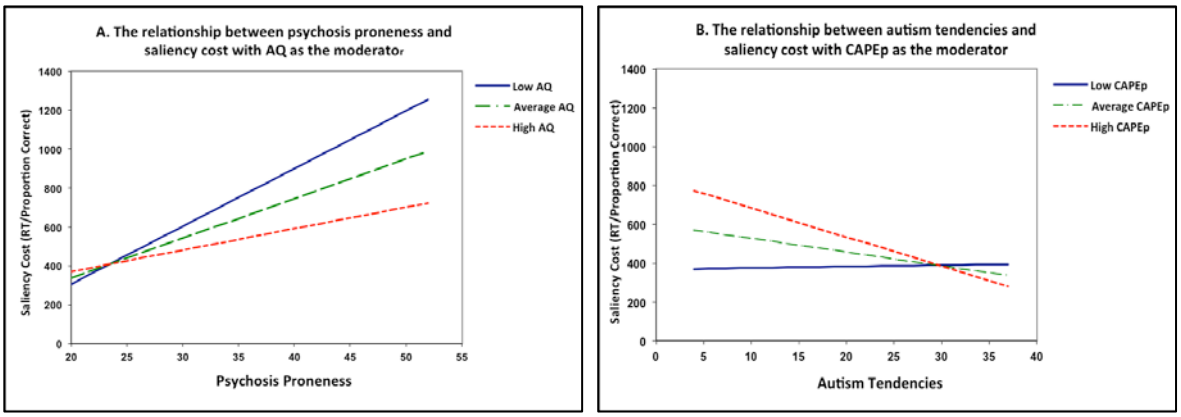

Figure 6. (A) Visualizes the association between psychosis proneness and saliency cost by plots of simple regression lines with low (-1 SD), average, and high (+1 SD) AQ scores as moderators. (B) Visualizes the association between autism tendencies and saliency cost by plots of simple regression lines with low (-1 SD), average, and high CAPEp scores (+1 SD) as moderators. Overall, saliency cost is increased with increasing psychosis proneness (Figure 6A), and decreased with increasing autism tendencies, especially when CAPEp score are average and above (Figure 6B).

3.2.2. The effect of autism tendencies and psychosis proneness on performance during the neutral condition

We investigated the association of autism, psychosis and their interaction on the cost incurred during the neutral condition only to see if they also explain simple effects of perception as in the neutral displays there is no need for attention selection or filtering. While the omnibus test of the overall model approached significant ($\chi^2_{(df=3)}$ =7.09, p=.07), all the parameter estimates were clearly non-significant (all *p*>.18).

3.3. The effect of autism attentional traits and psychosis proneness on saliency cost

The AQ includes two subscales that reflect attentional abilities, namely 'attention to details' and 'attention switching', where higher scores reflect increased focused of attention. To test the specific effects of these AQ traits and their interactive effect with CAPEp on saliency cost, we conducted an exploratory analysis whereby saliency cost was estimated as a function of CAPEp, attention switching and attention to details, and their 2-way interactions with CAPEp.

For the Global-Local task, the regression analysis revealed an overall significant model ($X^2_{(df=5)}$, =22.69, p<.001; R^2=.064), with parameter estimates showing significant positive association between saliency cost and CAPEp (β(±SE)=8.48(3.54), $X^2_{(df=1)}$=5.74, p=.017) and a significant negative association of saliency cost with the interaction term of attention switching x CAPEp (β(±SE)= -.83(.42), $X^2_{(df=1)}$=3.95, p=.047). No other main effects or interactions were observed.

Similar results were obtained in the Face-Scene task. Specifically, the overall model was significant ($X^2_{(df=5)}$, =12.91, p=.012; R^2=.109), with parameter estimates showing positive significant association between saliency cost and CAPEp (β(±SE)=16.57(7.70), $X^2_{(df=1)}$=4.64, p=.031) and attention switching (β(±SE)=53.42(25.53), $X^2_{(df=1)}$=4.38, p=.036). In addition, there was a significant negative association of saliency cost with the interaction term of attention switching x CAPEp (β(±SE)= -2.29(.91), $X^2_{(df=1)}$=6.29, p=.012). No other main effects or interactions were observed.

4. Discussion

The results of two experiments provide converging evidence suggesting that autism tendencies and psychosis proneness interactively reduce the cost incurred in the presence of salient distractors, but these interact such that the effect of the expression of one condition depends on the relative expression of the other condition. Specifically, higher psychosis proneness was generally associated with higher saliency cost, though when autism tendencies were also high this effect was non-significant (in the Face-Scene task), or even reversed (in the Global-Local task). Conversely, higher autism tendencies were generally associated with lower saliency cost, though in both tasks this effect was absent for participants with low psychosis proneness (Figures 4 and 6). Importantly, autism and psychosis expressions had no effects on other task variables (i.e., level/target or congruency), suggesting that this interactive effect is specific to salience suppression, and that the effect appears specific to attentional rather than perceptual abilities. These findings confirm that the filtering out of salient information is sensitive to the presence of sub-threshold clinical traits for ASD and PSD in healthy adults, and highlight the

importance of testing whether the processing of salient information in ASD or PSD is moderated by the relative expression of their co-occurring phenotypes.

However, what mechanism(s) might account for the interactive effect of autism and positive psychotic expressions on saliency cost reduction? An important clue comes from our findings showing that the interactive effect of autism traits with psychosis proneness on saliency cost reduction is driven by increased focused of attention, as measured by the attention switching subscale of the AQ [28]. Indeed, a common feature in accounts of attention is the presence of complementary but potentially competing processes for maintaining a focus of attention and for switching attention [47, 48]. These processes have been respectively associated with the coordinated action of the top-down (dorsal) and bottom-up (ventral) fronto-parietal networks, which play a prominent role in the processing of salient information [47]. Intriguingly, existing evidence indicates that these processes may be differentially affected by ASD and PSD, such that individuals with ASD show increased focus of attention [15, 28], and that individuals with PSD (and specifically those with positive symptom schizophrenia) show overswitching [49]. By considering these different attentional styles/tendencies, and the interactive neural networks with which they are associated (i.e., the dorsal and ventral attentional systems), it becomes apparent how overswitching and increased focused of attention can compensate for one another, particularly when the expressions of both autism and psychosis are high.

Another, but related, attentional mechanism that might account for the observed interactive effect on saliency cost is proactive and reactive attentional control [50]. In proactive control,

individuals bias attention by maintaining goal-relevant information and preventing interference in an anticipatory manner before the onset of the stimulus. Thus, proactive control can be called upon to effectively ignore salient distractors. In reactive control, individuals respond "online" to interference after the onset of the stimulus, and thus their responses to salient distractors appear to operate reflexively. Within the context of our tasks, participants must attend to task-relevant information and filter out salient but task-irrelevant distracting information, which suggests that these tasks may require proactive attentional control. In fact, previous research has shown that, in the Global-Local task used here, participants tend to rely on proactive processes preceding stimulus onset, and which appears to be modulated by the left posterior parietal cortex [51]. Thus, the fact that higher autism tendencies were generally associated with lower saliency cost may be due to a preferential bias towards proactive suppression in autism, which may be induced by a general failure in engaging the ventral attentional system [52]. Conversely, there is evidence suggesting that individuals with schizophrenia preferentially rely on reactive suppression [53], which could explain why psychosis proneness drives saliency cost in our tasks which require proactive processes. In this regard, a plausible prediction is that the use of reactive tasks would yield the reverse results—increased saliency cost in autism and decreased in psychosis. Taken together, our results could be accounted for by supposing that the effects of autism tendencies and psychosis proneness on salient distractors are respectively associated with preferential reliance on top-down (proactive) and bottom-up (reactive) modulation. Future research comparing performance on paradigms that tap reactive and proactive processes is important to confirm these predictions.

Furthermore, it is interesting to note that the anterior insula, which is an important hub of the salience network, appears to have a causal role in the initiation of cognitive control systems[54], including the default mode network and the central executive networks [55]. Thus, if autism and psychosis are preferentially associated with proactive and reactive modes of cognitive/attentional control, it may not be serendipitous that a recent structural MRI study [56] found that individuals with ASD have smaller grey matter volume in the anterior insula compared to those with schizophrenia in whom insular grey matter volume correlated positively with hallucinatory behavior. This opponency is consistent with evidence at the system level within the salience network whereby schizophrenia is associated with decreased functional connectivity [57], and autism with increased functional connectivity [18]. Thus, this is further evidence that the observed interaction of autism and psychosis expressions on saliency is intimately associated with interactive networks and structures that modulate the processing of salient information and which appear sensitive to the level autism and psychosis expressions.

Methodologically, while both tasks offer converging evidence on the interactive effect of autism tendencies and psychosis proneness on saliency cost, the Face-Scene perception task appears more sensitive in that it explains almost twice the variance afforded by the Global-Local task (R^2 = .092 vs .055, respectively). In addition, the inclusion of the neutral condition in the Face-Scene task provides an important insight as to whether the effects are due to attentional or perceptual processes.

Our study is the first to observe that co-occurring autistic tendencies and psychosis proneness exert interactive influences on saliency, which we suggest is possibly driven by contrasting attentional mechanisms that may be differentially affected by traits for autism and psychosis, and by implication in ASD and PSD. Our findings further suggest that previous reports assessing saliency as a function of one trait without assessing the other need to be viewed with some caution. This is because unmeasured differences in the proportion of one trait in a sample that was intended to look at the other trait might adversely affect results, and thus might account for some inconsistencies in previous literature. However, although no gender effect was observed, some caution regarding the generalizability of our findings is warranted given that our sample consists largely of female participants. In addition, while it is obvious that replications of our findings within the clinical populations are needed before any definitive conclusion can be made about how autism and psychosis impact one another, our findings may nonetheless have clinical implications. First, they imply that phenotypic variation in individuals diagnosed with either condition are likely to be a reflection of the relative expression of one disorder vis-à-vis the other, and raise the intriguing possibility that saliency-related abnormalities may be attenuated in individuals with comorbid ASD and PSD. Second, by showing that the effect of sub-threshold clinical expressions on saliency cost follow a similar trend to those observed in the clinical populations, we provide evidence that the risk of the disorder may, at least in part, be mediated by variation in the processing of salient information. Finally, our findings can inform cognitive attentional control-based interventions [58] in that they identify areas of strength and weaknesses of information processing as a function of the relative expression of autism and psychosis. In sum, our approach of simultaneously assessing

autism and psychosis expressions is potentially a useful framework for the development of behavioral interventions in both ASD and PSD, as well as to understanding the relationship between ASD and PSD and their concurrent effect on outcome and behavior.

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Supplementary Material

Description of the Global-Local Task

The task consisted of 4 blocks containing 32 trials each for a total of 128 trials equally divided among the 4 different conditions. On half of the trials, the compound figures consisted of the same global and local elements (congruent trials), and on the other half there were different global and local elements (incongruent trials). Each block was preceded with an instruction to either identify the letter at the *local* level or the letter at the *global* level. Participants, seated approximately 60cm from a 17" monitor, were asked to identify the presented letter as quickly and as accurately as possible. Details regarding stimuli's visual angles and positioning on the screen have been described elsewhere [43]. Each trial began with a 1500msec fixation cross. Letters appeared against a black background for 150msec, following a 200msec interval (see Figure 2B). The next trial began after the participant pressed one of two keys on the keyboard: 'K' and 'M'. 'K' was labeled 'S' and 'M' was labeled 'H'. Key presses recorded the participants' responses and reaction times. The task was presented using Presentation® (Neurobehavioral Systems, www.neurobs.com).

Description of the Face-Scene Perception Task

The task consisted of 12 blocks of 12 trials each for a total of 144 trials, equally divided among the congruent, incongruent and neutral conditions. Each block was preceded with an instruction to either identify faces or identify scenes as quickly and as accurately as possible. The instruction remained on the screen for 5 seconds. Each trial then began with a 1500msec fixation cross, and following a 200msec interval, the picture appeared for 150msec (see Figure

2C and 2D for a typical sequence display of congruent and incongruent stimuli, respectively). Participants were seated approximately 60cm from a 17" monitor, so that each centimeter on the screen represented ~0.96^{o} of visual angle. The displayed stimuli subtended a visual angle of ~12.82^{o} horizontally and ~12.84^{o} vertically. To be consistent with the response keys from the Global-Local task, the two faces and two scenes were associated with the same response keys on the keyboard: 'K' and 'M', relabeled 'S' and 'H'. Accordingly, participants were required to associate the scene or the face with the corresponding letter (H or S). Key presses recorded the participants' responses and reaction times. The task was presented using Presentation® (Neurobehavioral Systems, www.neurobs.com).

The participants' overall performance on the Global-Local task

The 2x2x2 repeated measure ANOVA reveals a main effect for congruency ($F(1,195)=420.71$, $p<.001$, $\eta_p^2=.68$) where participants were slower in the incongruent (M(SE)=640.96(8.57)) than the congruent (M(SE)=557.39(8.74)) condition. No other main effects were significant. Moreover, the 2-way interactions of level x congruency ($F(1,195)=238.67$, $p<.001$, $\eta_p^2=.55$), level x saliency ($F(1,195)=50.14$, $p<.001$, $\eta_p^2=.21$) and congruency x saliency ($F(1,195)=15.45$, $p<.001$, $\eta_p^2=.07$) were significant, as well as the 3-way interaction of level x saliency x congruency ($F(1,195)=64.19$, $p<.001$, $\eta_p^2=.25$). Follow-up analyses revealed significant saliency x congruency interactions at both the local ($F(1,195)=9.89$, $p<.001$, $\eta_p^2=.05$) and global levels ($F(1,195)=50.98$, $p<.001$, $\eta_p^2=.21$). Furthermore, as can be seen from Figure 3, the shift in salience from local salient (target salient) to global salient (distractor salient) when detecting the local letter, or the reverse (from global salient (target salient) to local salient (distractor

salient)) when detecting the global letter was associated with increased cost in both the congruent and incongruent conditions (all *ts*>5.6, all *ps*<.001). However, in the congruent condition, the effect of the cost associated with the shift from the local salient (target salient) to the global salient (distractor salient) at the local level (Cohen's *d*=.27) or with the reverse at the global level (Cohen's *d*=.43) was small, although the shift appears more costly at the local (M(SE)=62.45±7.43) than the global level (M(SE)=36.18±6.28) (t=2.69, df=195, p=.008, Cohen's *d*=.28). Conversely, the effects are larger during the incongruent condition when detecting either the local (Cohen's *d*=.56) or the global (Cohen's *d*=.73) letter. However, the shift appears more costly at the global (M(SE)=124.05±13.13) than at the local level (M(SE)=89.12±8.90) (t=2.05, df=195, p=.042, Cohen's *d*=.22). These results replicate the pattern of results observed in earlier studies using this task [42, 51], and suggest that the presence of a salient distractor has a measurable effect on processing cost.

The participants' overall performance on the Face-Scene Perception task

The 2x2x3 repeated measures ANOVA revealed a main effect for target (F(1,196)=58.48, p<.001, η_p^2=.23) where participants were slower responding to faces (M(SE)= 768.09(18.18) than to scenes (M(SE)=627.97(10.14); a main effect for saliency (F(1,196)=44.17, p<.001, η_p^2=.18) where participant were slower overall in the scene salient condition (M(SE)=742.71(15.58) than the face salient condition (M(SE)=653.35(10.63); and a main effect of congruency (F(2,392)=48.86, p<.001, η_p^2=.20) where participants were slower in the incongruent (M(SE)=772.47(17.78) than either the congruent (M(SE)=658.23(12.88) or neutral (M(SE)=663.37(9.29) conditions. There was no difference between the congruent and neutral

conditions (p=.56). Moreover, the 2-way interactions of target x saliency (F(1,196)=293.38, p<.001, η_p^2=.60), target x congruency (F(2,392)=44.24, p<.001, η_p^2=.18) and saliency x congruency (F(2,392)=37.48, p<.001, η_p^2=.16) were significant, as well as the 3-way interaction of target x saliency x congruency (F(2,392)=40.64, p<.001, η_p^2=.17). Follow-up analysis revealed only a main effect for saliency in the scene condition, where the shift from the scene salient (target salient; M(SE)=555.13±7.51) to the face salient condition (distractor salient; M(SE)=700.81±15.86) was associated with increased cost (F(1,196)=103.51, p<.001, η_p^2=.35). In the face condition, the analysis revealed a saliency x congruency interaction (F(2,392)=47.88, p<.001, η_p^2=.20). In this condition, the shift from face salient (target salient) to scene salient (distractor salient) was associated with increased cost and was significant for the neutral, congruent and incongruent conditions (all *ts*>8.14, all *ps*<.001, Cohen's *d*=.65-1.0). However, as can be seen from Figure 5, processing cost was significantly more pronounced in the incongruent condition when compared to the neutral (t=7.53, df=196, p<.001, Cohen's *d*=.71) or congruent conditions (t=6.95, df=196, p<.001, Cohen's *d*=.64). There was no difference between the congruent and neutral conditions (p=.63). Collectively, these findings show that the presence of a salient distractor has a measurable cost on target identification

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