Sad, Angry and Fearful Facial Expressions Interfere with Perception of Causal Outcomes

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Sad, Angry and Fearful Facial Expressions Interfere with Perception of Causal Outcomes

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Abstract

Facial expressions convey a speaker's emotional state, facilitating the prediction and interpretation of their thoughts and behaviours. Interactive feedback during social interactions provides statistical evidence, for the basis of a causal percept which allows understanding of conversations. We aimed to determine whether emotional expression affects sensitivity to contingent relationships and whether this sensitivity is guided by the statistical evidence for causality. In Experiments 1-3, we tested happy and sad facial expressions and non-emotional control stimuli (e.g., shapes) and varied contingent emotional expressions (negative, zero, and positive contingency) as well as outcome frequency (low, moderate, and high). Participants' judgements of contingency were based on a probabilistic learning process rather than simple pairing or prior knowledge and they perceived a weaker sense of causality with sad faces than either happy faces or non-emotional control stimuli. Finally, in Experiment 4, we tested threat-related angry and fearful faces alongside happy faces. The results showed that participants could learn the statistical contingent relationships with faces but still perceived a weaker sense of causality with angry, and fearful faces compared to happy faces. Overall, the results suggest that learning was guided by statistical evidence, but aversive expressions (those with negative valence) were less effective. We discuss this result in relation to the stimulus properties (i.e., salience) of faces, the content of emotive expressions and how these impact learning.

Keywords: Contingency learning, Emotion and attention, Happy faces, Negative facial expressions, Stimulus saliency, Attentional control

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Introduction

Facial expressions are powerful tools conveying social information. Even if we do not understand the language of a conversation, we still interpret the interaction between two people by observing the expressive facial exchange (Barros et al., 2023; Calvo & Marrero, 2009; Fischer & Manstead, 2008). From an observer's perspective, watching the facial exchange provides information about the speaker's and listener's current and future state, and can inform predictions of future interactions (i.e., a smile may predict a smile in another person, which in turn feeds back to the originator; Kret, 2015; Saylik et al., 2025). Indeed, such interactive feedback during social interactions constitutes contingent evidence that can be examined within the context of information processing (Saylik et al., 2025). If we do perceive the statistical relationships between two successive events such as cue and outcome, this perception seems to generate a sense of causality (Murphy et al., 2017; Heisz et al., 2011).

The learning of contingent information as studied previously with non-facial stimuli assumes that processes of perception, attention and memory support learning of contingency (Byrom & Murphy, 2019; Mackintosh, 1975; Pearce et al., 1998; Pearce & Mackintosh, 2010a). Research suggests that such learning requires attentional resources influenced by stimulus features (Jianming Zhu, Radulescu & Bennett, 2023). In the case of faces, this may include features such as lip movements, eye placement, and wrinkles (Barros et al., 2023; Beaurenaut et al., 2023; Calvo & Marrero, 2009; Jianming Zhu, Radulescu & Bennett, 2023), which vary depending on the contingent interactions between conversational partners.

The evidence suggesting that facial stimuli might be processed differently to non-facial cues arises from several lines of research (Becker et al., 2011; Lemaire, 2021). These findings commonly highlight the unique salience and attention-grabbing properties of facial

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expressions, noting that the degree to which emotional faces capture attention may vary depending on the specific emotion being expressed.

One line suggests that aversive facial expressions may be hyper-salient, facilitating allocation of attentional resources (Barros et al., 2023; Calvo et al., 2018; Kim et al., 2019). Aversive expressions, which are those with negative valence (e.g., sad, angry, and fearful), have been proposed to be more salient than positive expressions for speculative evolutionary reasons. For instance, the ability to quickly process threat signals may have provided a survival advantage, allowing detection of danger without relying on the broader context (Barros et al., 2023; Calvo et al., 2006; Lundqvist et al., 2014; Öhman et al., 2012; Pinkham et al., 2010). Another line of research focuses on the perceptual salience of the expressions themselves, suggesting that happy expressions may be more visibly discriminable than other expressions (e.g., sad, angry, fearful) due to their distinct physical characteristics (Barros et al., 2023; Becker et al., 2011; Calvo et al., 2018; Calvo & Nummenmaa, 2008). For example, Stuit et al. (2023) showed that happy faces receive attentional priority compared to angry and neutral faces in a detection task, due to perceptual differences (e.g., contrast energy) rather than emotional content. Overall, both lines of research suggest that emotional expressions (e.g., happy, sad, angry, fearful) are processed more easily than neutral stimuli. The present experiments aimed to test whether and how people learn these emotive contingencies and whether facial expressions support statistics-based learning.

Experiment 1

In Experiment 1, we tested whether emotive expressions involving statistical relations are learnable and we were interested in whether this information might have privileged access in processing. We examined three types of contingent relationships, where the statistical association between two faces was either positive, negative, or uncorrelated. Contingencies

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were constructed by manipulating four types of evidence relevant to a contingency or correlation: the co-presence and co-absence of a particular emotion in both the transmitter and the receiver, and the presence and absence of each emotion independent of one member of the dyad. Two types of facial stimuli (happy or sad) were taken from the Radboud Faces Database (RAFD; Langner et al., 2010). The RAFD images are matched for perceptual salience (Langner et al., 2010). They consist of images that are matched for factors such as facial landmarks, lighting conditions, and image background. This face database is widely used (Jaeger, 2018) and has a recognition accuracy of 88% across different cultures (Mishra et al., 2018). We also used a control condition in which participants were required to report the contingency related to non-emotive stimuli (i.e., geometric shapes, hexagons, and triangles).

Methods

Participants

We recruited 126 participants from an opportunistic university sample with the aim of having a final sample size of 100 participants based on previous effect sizes in our lab using a similar streaming procedure (Witnauer et al., 2023). Nineteen participants were excluded based on the exclusion criteria: 7 (aged 19–25; 4 females) had a current or past psychiatric disorder, and 11 (aged 20–28; 8 females) scored high on the BDI. Following exclusions, the final sample consisted of 107 participants (56 females, 41 males) aged between 18 - 30 years (males: *M* = 20.24, *SD* = 1.34; females: *M* = 19.50, *SD* = 1.55). Participants were either native English speakers or fluent in English, based on self-reports. Participants provided written informed consent and were offered an honorarium of £10 for 1.5 h. The central University ethics committee at the University of Oxford approved the study: [R60997].

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Materials

We used a questionnaire to exclude participants with a history of or current psychiatric or neurological disorders, as well as those currently using psychoactive medication. Beck's Depression Inventory (BDI) was administered to control for potential confounding effects due to depressive mood, which may impair contingency discrimination (Msetfi et al., 2009). Participants scoring higher than 20 were excluded (*M*=12.33; *SD*= 3.94; Beck et al., 1988). A survey of alcohol and caffeine consumption was conducted to control for their stimulating effects. Participants who consumed more than 3 alcoholic drinks or more than 8 caffeinated beverages on the day prior to the experiment were excluded. IQ was estimated using demographic characteristics (age, gender, years of education, and occupational classification) (Crawford & Allan, 1997; *M*=112.17; *SD*= 5.54) which correlates with the Wechsler Adult Intelligence Scale-Revised (WAIS-R). Factors such as IQ, alcohol and caffeine consumption, and BDI scores can influence performance on cognitive tasks; therefore, we measured and controlled for these variables to minimize their potential impact (Msetfi et al., 2015, 2017; Nehlig, 2010; Weissenborn & Duka, 2003).

Contingency task

Stimulus presentation and response measurement was controlled by Gorilla Experiment Builder (Anwyl-Irvine et al., 2020), running on a Mac-book Pro (Apple, Inc). Participants sat approximately 60 cm from the screen in a dimly lit room. We used images of 10 individuals (5 female and 5 male) from the Radboud Faces Database (RaFD; Langner et al., 2010). Each individual contributed three facial expressions—neutral, sad, and happy—resulting in a total of 30 facial images. During the practice session, images of two individuals displaying neutral, sad, and happy expressions were used. In the actual experiment, images of eight individuals

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with the same expressions (neutral, sad, and happy) were used. For the non-emotional stimuli, we used geometric shapes (i.e., triangles and hexagons; Figure 2a).

Each cue–outcome trial lasted 1000 ms and was displayed in the center of a white screen. Each predictive cue was presented alone for 250 ms on the left side of the frame. Immediately after, the outcome appeared adjacent to the predictive cue for 500 ms. A fixation cross then appeared for 250 ms before the next trial began. From the perspective of a statistical account of learning (e.g., Allan, 1980; Baker, Murphy & Vallee-Tourangeau, 1996), we varied how predictive each facial expression cue was for its facial expression outcome by varying four types of event. An *a* event refers to the cue(C) and the outcome (*O*), both present-(e.g., a smile on both faces); A *b* event represents the cue being present (*C*) but the outcome being absent (~*O*) (a smile on the speaker but not the listener); *c* events were when the cue is absent (~*C*) but the outcome is present (*O*) (a smile on the listener but not the speaker; and finally *d* events are those when both the cue and the outcome are absent (~C and ~O) neither face showing a smile); Note that on each trial two faces were presented and it is the emotion that was expressed or not. Table 1 describes Allan's (1980) metric Delta P (ΔP), which is the one-way contingency between two binary events. Δ*P* generates a value between -1 and +1, much like a correlation coefficient. The relation becomes more positive as the frequency of a and d events increases whereas the relation goes towards a negative contingency as the frequency of b and c increase (e.g., a particular expression predicts a decrease in the likelihood of that expression in the listener) (Allan, 1980; Allan & Jenkins, 1983; Crump et al., 2007; Murphy et al., 2022).

One factor had three levels of type of cue and outcome (happy and sad faces or shapes). In each of the conditions with faces, there were two people. The gender of each face, nominally provided by RaFD but not explicitly marked, was randomized (labelled as Person A and

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Person B) on each trial, as shown in Figure 1. The cue was the first person's expression, and the outcome either reflected the same emotion as the initial face or a neutral expression.

An *a*-events showed both individuals displaying the same emotional expression (e.g., both happy). *b* and *c* events were represented by either the face on the left of the screen or the right of the screen expressing an emotion while the other remained neutral (e.g., one happy, one neutral). When neither event was present (*d* events), both individuals displayed neutral expressions.

--- *Insert Figure 1 about here* ---

In the control condition illustrated in Figure 2, the cue was a blue triangle, and the outcome was a blue hexagon, both matched in size (height 9 cm, width 6 cm). There were four possible cue-outcome pairs, each counterbalanced to represent the four possible conjunctions of two binary events as described for the face conditions.

--- *Insert Figure 2 about here* ---

This was a within-subject design with three stimulus types and three statistical relations with moderate strength of positive and negative conditions and equal distribution of cells in zero contingency ($\Delta P = +.50, 0, -.50$) as shown in Table 1. The distribution of events was adjusted to achieve these specific Δp values. There were nine conditions in total, each consisting of 60 trials, repeated four times, for a total of 240 trials for each condition. The emotional conditions were repeated with identical Δp values (i.e., positive, zero and negative); however, the pairs of faces used in each round were different. Thus, predictor faces varied in emotional content for each condition, the top row of each table, but the emotional content of the outcome was kept equivalent across conditions. The experimental design reflected the full factorial design: 3 contingencies (Positive, Zero and Negative), x 3

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types of stimuli (Happy, Sad and Shape). Hence, participants provided 36 ratings (4 repetition x 9 conditions). The 9 conditions were fully randomized across the repetition cycle for each participant. At the end of each condition, participants were asked to provide a judgment of the relation between the two stimuli on a scale ranging from -5 to +5 with +5 indicating a very strong positive relation, -5 representing a very strong negative relation and 0 representing no relation.

--- Insert Table 1 about here ---

Procedure

After participants read the information sheet and consent form, they completed screening questionnaires followed by the task. Participants were instructed that, on each trial, two images would be presented rapidly, with four possible events described below in the instructions. In the emotional conditions, they saw two people, one presented on the left (Person A) who initiated a conversation and the other on the right who agreed to chat. The stream involved Person A and their emotional expression and then Person B's response expression. Like a conversation, the emotional state of one person (transmitter) could be thought to trigger a reaction in the other person (receiver) or leave them unaffected. This suggests that Person B's expression might have been caused by Person A's expression. Participants were then asked to imagine two people engaging in a conversation while attentively observing the stream of cue and outcome pairs.

At the end of the presentation, participants were asked to judge the relationship between the facial expressions of Person A and Person B — whether the emotion of Person A predicted the presence or absence of emotion in Person B. In the shape condition, they were asked to judge the relationship between two figures — a triangle and a hexagon — and whether the triangle predicted the presence or absence of the hexagon. Along with the instructions,

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participants received a set of three practice conditions with positive, zero and negative conditions which were identical to the training conditions (60 trials in 1 minute). The ratings provided during these conditions were similar to those reported in the analysis. On average, the practice session lasted about 5 minutes. This was done to minimize any comprehension difficulties. Practice data was not used in the analysis. A brief presentation of instructions was as follow.

"Hello! In this part, you'll complete a task involving either emotional faces or shapes, with several different conditions. In each trial, two images will be shown in quick succession.

Emotional Condition:

Imagine a conversation between two people, represented by faces on the left and right. Person A (left) initiates the conversation, and Person B (right) responds. You'll see their emotional expressions as the conversation unfolds. Person A's expression may influence Person B's expression positively, negatively, or not at all. You will rate how strongly the emotional expression of Person A predicts the emotional expression of Person B on a given scale. Possible events include:

1. *Both Person A and B are sad.*
2. *Person A is sad, but Person B is not.*
3. *Person A is not sad, but Person B is.*
4. *Neither Person A nor B is sad.*

   These combinations also apply to happy expressions.

Shape Condition:

You will rate how strongly the triangle predicts the hexagon on a given scale. The triangle

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may positively or negatively predict the hexagon, or there may be no relationship. Consider the frequency of these four events when making your assessment:

A. Both triangle and hexagon appear.

B. Triangle appears, but hexagon does not.

C. Triangle does not appear, but hexagon does.

D. Neither triangle nor hexagon appears.

Let's start with some practice!"

Data Treatment and Statistical Approach

All analyses were conducted in SPSS (v25). For Experiments 1, 2, and 4, we performed repeated-measures ANOVAs with the within-subject factors Stimulus × Contingency. For Experiment 3, we included an additional within-subject factor, Strength (Stimulus × Contingency × Strength). When significant interactions emerged, we conducted follow-up ANOVAs within each contingency condition. Effect sizes are reported as partial eta squared (η^2_p). Significant results are reported at $p < .05$ unless otherwise corrected. Bonferroni adjustments were applied to control for multiple comparisons, corresponding to $\alpha = .025$. Bonferroni adjustments were applied to control for multiple comparisons, corresponding to $\alpha = .025$. These and all subsequent post hoc comparisons were evaluated at an alpha/n–1 Bonferroni correction for Type I error. Main effects of contingency were always examined, regardless of significant interactions, as a manipulation check to confirm that the programmed contingencies were discriminable.

Results and discussion

The descriptive statistics suggest that participants could easily discriminate between the three contingencies in all three stimulus conditions (i.e., happy, sad and shape) and that judgements

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differed between some of the stimuli but only in the positive and negative conditions. As shown in the left panel of Figure 3 (Panel A), participants' mean judgments for the three contingencies aligned with the programmed statistical relations, positive was judged higher than zero which was judged higher than negative. Compared to the shape and sad conditions, the happy condition showed some advantage in distinguishing between the different relationships. The evidence supporting these finding is based on a 3x3 factorial ANOVA, which included the within-subject factors of stimulus type (happy, sad, and shapes) and contingency (positive, zero, negative). The interaction [$F\ (4, 103) = 52.82, p < .001, \eta^2 = .333$)] and both main effects [Stimuli, $F\ (2, 105) = 5.38, p < .001, \eta^2 = .050$] and [Contingency, $F\ (2, 105) = 136.28, p < .001, \eta^2 = .904$)] were reliable. The mean differences for these pairwise comparisons on the contingency main effect for positive vs. zero and zero vs. negative, respectively, were all consistent with the previous experiments for happy (MDs = 2.74, 2.93), sad (MDs = 1.85, 1.90), and shape stimuli (MDs = 2.41, 2.96), all significant (all ps < .001). Overall, age and gender were not significant covariates across contingency tasks ($F<1, p>.2$) and were removed from the analysis.

Contingency-Specific Findings

To understand the interaction, we tested whether the ratings were similar for each stimulus type in each contingency. The conclusions are that happy faces were rated more positively than the other two stimulus types when presented with a positive contingency. There were no stimulus differences for the zero contingency. Happy faces were rated more negatively than sad for the negative contingency. Surprisingly though, shapes were more similar to happy than sad with sad eliciting the weakest ratings. We report the main effect of stimulus and the post hoc comparisons between each pair of stimuli.

Positive contingency conditions: The one way (Stimulus Type: happy, sad, shape) repeated-measures ANOVA revealed that participants consistently rated the happy stimulus more

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positively than sad and shape. This was supported by a significant main effect of stimulus *F (2, 105) = 26.15,* p< *.001,* η^2_p *= .198* and three post hoc comparisons demonstrated significant differences in ratings. Conditions with happy faces were rated more positively than those with sad faces (Mean Difference, MD = 0.96, SE = 0.12, p < .001, 95% CI [0.67, 1.25]); and shapes (MD = 0.45, SE = 0.12, p = .001, 95% CI [0.16, 0.74]). In addition, the conditions with shapes were rated more positively than those with sad faces (MD = 0.51, SE = 0.16, p = .005, 95% CI [0.13, 0.88]).

Zero contingency conditions: A similar ANOVA revealed no effect of stimulus type F *(1, 105) = 3.60,* p= *.055,* η^2_p *= .035.*

Negative contingency conditions: The one-way repeated-measures ANOVA revealed a significant main effect of stimulus type, *F (2, 105) = 66.95, p < .001,* η^2_p *= .387*. Three post hoc pairwise comparisons conducted within the negative contingency condition revealed significant differences in ratings. The condition with happy faces was rated more negatively than the sad face condition *(MD = -0.63, SE = 0.08, p < .001, 95% CI [-0.82, -0.43])*. Furthermore, the condition with shape stimuli was rated more negatively than both the conditions with sad *(MD = -1.25, SE = 0.12, p < .001, 95% CI [-1.56, -0.95])* and happy faces *(MD = -0.63, SE = 0.11, p < .001, 95% CI [-0.90, -0.35])*.

--- Insert Figure 3 about here ---

Experiment 1 demonstrates clearly that participants are able to discriminate contingencies with facial expressions, thereby replicating and extending findings related to contingency sensitivity and the streaming procedure with neutral cues (e.g., Murphy et al., 2022; Witnauer et al., 2023). What was particularly interesting was the ratings were moderated by the type of emotional expression. Overall, the contingencies with sad faces were judged to be less contingent with their consequent expression than happy faces or even neutral symbols.

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Interestingly, this may indicate that sad faces diminish the sense of causality compared with happy faces. In principle, if emotional content simply biased attention and learning then we might have expected both expressions to elicit stronger ratings compared with shapes. Our evidence also supports the hypothesis that facial changes can be distinguished based on statistical contingency. We sought to demonstrate that a facial expression could support statistical learning and on the surface this evidence is consistent with that hypothesis. However, it is possible that the ratings were influenced primarily by the stimulus and less by the contingency in spite of the statistically significant contingency effects.

While each contingency condition involved a similar number of outcome events (i.e., 30), the three conditions involved very different numbers of pairings of the cue and outcome (8, 15 and 22) for the negative, zero, and positive conditions respectively. Therefore, the contingency effect might reflect the number of times each cue and outcome was presented within a condition rather than the overall contingency. We return to this possibility in Experiment 3.

We have also assumed that any differences between the three stimuli reflected their content, happy, sad or shape. We might have been particularly concerned about our conclusion that facial expressions elicit more extreme ratings that shapes, if the shape had elicited ratings that were much lower than the faces. We found that shapes were intermediate to happy for the positive condition but shapes were rated more strongly negative than happy shapes and so shapes were not as different from faces as we initially assumed. The faces were taken from validated stimuli equated for expressive content (Langner et al., 2010). Perhaps our shapes may have been particularly salient for supporting learning? For the shape stimuli, we relied on the presence or absence of simple geometric shapes (e.g., triangle or hexagon) against a blank background as a relatively neutral stimulus that is similar to cues used in previous

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contingency learning research (e.g., Murphy et al., 2021). Our choice may have inadvertently increased the salience of the shape stimuli relative to the faces, potentially contributing to the relatively strong learning of shapes in comparison to the sad condition. The finding that shapes were more effective than sad faces made us consider whether our shapes were not sufficiently similar in terms of perceptual load and perhaps the faces were themselves quite complex, undermining perception of the emotional content, although this runs against evidence suggests that faces have privileged processing (Barros et al., 2023; Calvo et al., 2018; Kim et al., 2019). And regardless of the nature of our shape stimuli, it is also the case that happy and sad were significantly different in their ability to support the statistical learning required for the positive and negative relations.

Experiment 2

Experiment 2 sought to replicate our findings and adjust the perceptual characteristics of our stimuli to minimize perceptual differences. The face stimuli in Experiment 1 relied on the presence or absence of the emotion expressed by the face (e.g., happy or neutral expression for the presence or absence of happy) but there was always a face, whereas the shapes relied on presence or absence of triangle/hexagons against a blank background. Absent expressions involved a fully formed face with no emotion, whereas the shapes involved their presence or complete absence, a blank box. This difference between the presence and absence of each stimulus type may itself have been supportive of learning by enhancing the attentional capture of the shapes, contributing to their strong learning.

In Experiment 2, we made several adjustments to balance the shape and emotion conditions. To start, we replaced the hexagons and triangles with patterned ovoid shapes, such as ovals, circles, and semicircles as displayed in Figure 4, which visually represented a visual space that was similar to the faces. This change allowed us to modify the shape conditions by

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varying the presence or absence of a pattern, mirroring the presence or absence of emotion in the face conditions. We also adjusted the presentation of faces, rather than the vivid colour versions used in Experiment 1, which were chosen for their realism, we chose black-and-white faces through an ovoid window, as shown in Figure 5 that may have supported learning that was more similar to the shapes.

Additionally, in Experiment 1, the predictive cue and the consequent outcome were presented for different durations. Learning cue-outcome relations has been shown to be reliant on the durations of presentations of the cues and therefore by standardizing the duration of stimuli presentation so that both the cue and outcome were shown for the same duration of time, we sought to equate the learning of both events. Further and unlike in Experiment 1, where stimuli were presented sequentially, we opted for a simultaneous presentation of cue and outcome. Although sequential presentation of cues is relevant for a model of facial interactions, it is also the case that the presentation of cue and outcome still involves a temporal component as participants must shift their gaze sequentially from left to right and back again as they process the two cues. Sequential or simultaneous processing during the rapid streaming procedure has been shown to have minimal impacts on contingency sensitivity (Murphy et al., 2022). Finally, the total number of trials during each condition was reduced from 60 to 24 based on similar experiments with fewer trials that seem to have little effect on learning (Murphy et al., 2022). We anticipated that controlling these factors might result in more similar effects for faces relative to the neutral shape condition.

Methods

Participants, task, and procedure

In accordance with the exclusion criteria, three out of 85 (3 females aged between 21-22) participants who scored high on the BDI were excluded. The final sample consisted of

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eighty-two participants (38 females, 43 males) aged between 18 and 30, recruited from a university sample (males: M = 20.90 years, SD = 1.50; females: M = 20.60 years, SD = 1.98). The procedure was the same as Experiment 1 except where noted. We modified the presentation of stimuli to 750ms, presenting cue and outcome simultaneously and reducing number of trials in each stream (from 60 to 24) while maintaining the same contingencies created from fewer trials as shown in Table 2. As the face pairs changed across repetitions, we used different patterned shape pairs (e.g., an oval and a circle or two semicircles) for each repetition (see Figure 4). For example, in tasks with non-emotional stimuli, the cue could be a pattern displayed in the oval, and the outcome could be the pattern shown in the circle. In another repetition, the cue and outcome might be patterns presented in the two semicircles. Similarly, presentation of the faces was modified by showing black-and-white images through an ovoid window, as illustrated in Figure 5.

--- Insert Table 2 about here ---

--- Insert Figure 4 about here ---

--- Insert Figure 5 about here ---

Results and discussion

In line with Experiment 1 and as shown by ratings in Figure 3-Panel B, participants' mean judgments suggest that the discriminations between the three contingencies were in line with the statistical relations and that again there was a disadvantage for the sad facial expressions. As in Experiment 1, we started with a 3x3 factorial ANOVA Stimulus (i.e., happy, sad, shape) x Contingency (positive, zero, negative). The results demonstrated an overall significant interaction $[F\ (4, 78) = 8.75,\ p < .001,\ \eta 2 = .13]$ suggesting that discrimination was not equivalent for each stimulus type. While the main effect of stimulus was not

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significant, the main effect of contingency was [$F (2, 80) = 340.50, p< .001, \eta 2= .85$]. The mean differences for these pairwise comparisons for positive vs zero and zero vs negative respectively were all consistent with the experiment 1 for happy (MDs = 2.89, 3.21), sad (MDs = 2.40, 1.30), and shape stimuli (MDs = 2.97, 2.70), all significant (all ps < .001) Given the significant three-way interaction and our interest in the stimulus differences we conducted separate one-way ANOVAs within each contingency. Like Experiment 1, sad faces trained with positive or negative contingencies did not elicit as extreme positive or negative ratings respectively. Interestingly ratings of shape were not rated differently from happy as shown below.

Contingency-Specific Findings

Positive contingency conditions: The one-way stimulus type repeated-measures ANOVA (Stimulus: happy, sad, shape) revealed a similar pattern to Experiment 1: participants consistently rated happy and shape stimuli more positively than sad stimuli. The main effect of stimulus was significant F $(2, 78) = 14.64$, p$< .001, \eta^2 = .156$. Post hoc pairwise comparisons revealed that happy stimuli were rated more positively than sad, $MD = 1.18, SE = 0.24, p < .001$, *95% CI [0.59, 1.76]*, and shapes were rated more positively than sad, $MD = 0.85, SE = 0.25, p = .003$, *95% CI [0.24, 1.46]*. However, happy and shape did not differ significantly, $MD = 0.33, SE = 0.18, p = .218$, *95% CI [-0.11, 0.76]*.

Zero contingency conditions: There were no differences between the three stimuli F $(2, 78) = 3.21$, p$= .070, \eta^2 = .060$.

Negative contingency conditions: There was a main effect of stimulus F $(2, 78) = 16.82$, p$< .001, \eta^2 = .175$. Post hoc pairwise comparisons revealed that happy stimuli were rated more negatively than sad, $MD = -1.23, SE = 0.27, p < .001$, *95% CI [-1.90, -0.55]*, and shape stimuli were rated more negatively than sad, $MD = 1.11, SE = 0.20, p < .001$, *95% CI [0.63,*

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1.59]. However, happy and shape did not differ significantly, *MD = -0.11, SE = 0.22, p = .616, 95% CI [-0.43, 0.66]*. These findings mirrored the pattern observed under positive contingency conditions, where happy and shape also did not differ significantly and sad was perceived with weaker perception of causality.

Experiment 2 replicated the findings related to the differences between happy and sad faces demonstrated in Experiment 1. One of the goals of Experiment 2 was to attempt to equate the stimulus properties between faces and shapes. The result of these changes has been to reveal that happy faces do not improve contingency rating sensitivity; rather, sad faces appear to diminish contingency ratings.

The absence of an effect with zero contingencies is consistent with the result of Experiment 1 and encourages the conclusion that participants are sensitive to the statistical relations being trained. When the objective contingency suggests no relation, participants ratings accurately reflect the lack of relation. The fact that ratings in the positive contingency conditions were significantly higher than those in the zero contingency conditions confirms that participants' judgments were guided by the actual contingency between cues and outcomes, rather than by the emotional content of the stimuli alone. In other words, happy stimuli did not simply lead to more positive or less negative ratings. The results from Experiment 2 like Experiment 1 are somewhat inconsistent with one of our hypotheses, that faces (happy or sad) would provide a more salient and learnable context in which to learn contingencies compared with neutral shapes. It seems rather that sad facial expressions, at least these validated stimuli, interfere with learning or interfere with the ability to differentiate statistical contingency.

Although these findings support the hypothesis that pairs of faces can be perceived in terms of their statistical relatedness, the results regarding the stimulus type contradicts our initial hypothesis, but they do align with previous research suggesting that some facial expressions

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are linked to weaker learning (e.g., sad), while happy expressions might support attentional focus and enhanced learning (Averbeck & Duchaine, 2009; Fulcher et al., 2001; Saylik et al., 2021; Yuan et al., 2023). Both affective and visual-based accounts support an advantage for happy faces (Stuit et al., 2023; Yuan et al., 2023) however, given our findings regarding shapes, there is little evidence for a happy face advantage.

Experiment 1 and 2 demonstrated contingency sensitivity and we have suggested that the effect is attributable to the overall statistical relation. It is also the case that the three conditions (Positive, Zero and Negative) differed on the basis of the number of contiguous pairings of the cue and outcome, the 'A' events (i.e., the times the contingent events occur together from the DP formula). To counter the possibility that the effect was simply based on the number of pairings between the two similar facial expressions, we introduced specific control conditions in Experiment 3. These conditions kept the number of pairings (i.e., A events) constant while manipulating the overall statistical relationship between cues and outcomes. There is good evidence that sensitivity to contingency can be impaired by biased training sets (e.g., Vallée-Tourangeau, Hollingsworth & Murphy, 1998a) and therefore these new conditions should be able to resolve whether the learning was based on the overall statistical relation.

Experiment 3

In Experiment 3, we extended the range of contingencies to generalize our effect and rule out the potential confounding hypothesis for the contingency effects in Experiments 1 and 2. If the participant's ratings simply reflected a sensitivity to the number of cue-outcome pairs *(cell a;* the trial with same expression on both faces*)* then we should be able to alter the number of pairings, while maintaining the contingency to assess learning. Consider, for example, the trial type frequencies presented in Table 2 from Experiment 2. The participants

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rated positive contingencies higher than zero contingencies, which were in turn rated higher than negative contingencies, but notice that rather than overall contingency the ratings correlate with the number of times that the two faces had the same expression (9, 6 and 3 times respectively as shown in Table 2; see also Vallee-Tourangeau et al., 1998). To this end, in Experiment 3, we tested different strengths of positive and negative contingency by manipulating the cue and outcome frequencies to obtain weak and strong conditions. We predicted that the strong positive condition (7 pairings as shown in Table 3) would be rated as more contingent than the strong zero condition (also 7 pairings) although both conditions received identical numbers of the cue and outcome together. Similarly, the weak zero condition (with 1 pairing) was predicted to be judged more positively than the strong negative condition despite their equivalent number of cue outcome pairings (i.e., 1 time). We also hypothesized that the strong zero condition (7 pairings) would be rated less positively than the weak positive condition (5 pairings), despite actually having more cue–outcome pairings. Finally, we also expected the weak zero condition (1 pairing) to be rated more positively than the weak negative condition (3 pairings), despite involving fewer pairings. One other change involved reducing the number of trials from 24 to 16 to reflect evidence that learning may have been reaching a ceiling or asymptote early in training given other experiments in our lab (Murphy et al., 2022). This final change might have worked against us finding evidence for the contingency effect since pre asymptotic learning might mask subsequent learning differences. This worry was not borne out by the data analysis.

Methods

Participants, task, and procedure

In accordance with the exclusion criteria, 10 participants (8 females: *M = 22.00, SD = 2.36; 2* males: *M = 23.75, SD = 5.57*) out of 100 were excluded due to either a history of

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depression or anxiety, or high scores on the Beck Depression Inventory (BDI). The final sample consisted of 90 healthy university participants (48 females, 42 males) aged 18–27 years (males: *M = 22.38, SD = 1.72*; females: *M = 20.28, SD = 1.83*). The methods matched those in Experiment 2, with one exception: we used two statistical strength levels (Weak and Strong) for each contingency, defined by Δp values, shown in Table 3.

--- Insert Table 3 about here ---

Results and discussion

In line with Experiment 1 and 2, and as shown by ratings in Figure 5, participants judged the sad face conditions to be both less positive and negative than either happy or shape conditions. We also replicated the contingency discrimination across positive, zero, and negative conditions, with participants' judgments aligning with the overall contingencies. Importantly for the pairing hypothesis, there was strong evidence that participants were learning the overall emotion-based contingencies and not simply basing judgements on the number of cue–outcome pairings.

We started by conducting an overall omnibus 3 × 3 × 2 factorial ANOVA with factors Stimulus Type (Happy, Sad, Shape), Contingency (Positive, Zero, Negative), and Strength (Weak, Strong). Results revealed a significant three-way interaction $[F(4, 86) = 4.39, p = .004, \eta^2 = .055]$, as well as two-way interactions for Contingency × Strength $[F(2, 88) = 183.36, p < .001, \eta^2 = .681]$ and Contingency × Stimulus $[F(4, 86) = 23.69, p < .001, \eta^2 = .216]$. Main effects were also significant for Strength $[F(1, 89) = 14.27, p < .001, \eta^2 = .142]$ and Contingency $[F(2, 88) = 856.70, p < .001, \eta^2 = .909]$. However, all other effects were non-significant, including Stimulus × Strength and the main effect of Stimulus Type (max F

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= 2.94, min p = .104, $\eta^2 \leq .030$). Given the significant three-way interaction, follow-up 3 (Stimulus Type) × 2 (Strength) ANOVAs were conducted separately within each contingency level. However, before reporting these interactions, it is worth confirming that for each stimulus type, positive contingencies were rated more positively than zero and zero contingencies were rated more positively than negative contingencies. The mean differences for these pairwise comparisons for positive vs zero and zero vs negative respectively were all consistent with the previous experiments for happy (MDs = 2.93, 2.74), sad (MDs = 1.90, 1.85), and shape stimuli (MDs = 2.96, 2.41), all significant (all ps < .001).

Contingency-Specific Findings

Positive contingency condition: A 3 (Stimulus Type: happy, sad, shape) × 2 (Strength: strong, weak) repeated-measures ANOVA revealed that participants consistently rated the conditions with happy faces and shapes more positively than sad faces, and stronger contingency strength (+.75) led to higher ratings than weaker positive strength (+.25) across all stimulus types. The analysis revealed no significant interaction between stimulus type and strength, $F(2, 88) = 0.92, p = .401, \eta^2_p = .011$. However, there were significant main effects of stimulus type, $F(2, 88) = 26.38, p < .001, \eta^2_p = .235$, and strength, $F(1, 89) = 201.20, p < .001, \eta^2_p = .701$. These effects were consistent with the observation that happy and shape stimuli were rated more positively than sad faces even though across all stimulus types, participants gave higher ratings in the strong conditions. To confirm the stimulus effect, which followed a similar pattern to Experiments 1 and 2, post hoc pairwise comparisons showed that both happy stimuli *(MD = 1.14, SE = 0.18, p < .001, 95% CI [0.69, 1.59])* and shape stimuli *(MD = 0.90, SE = 0.18, p < .001, 95% CI [0.46, 1.35])* were rated significantly more positively than sad stimuli. However, as in Experiment 2 and suggested by Figure 5, happy and shape stimuli did not differ significantly *MD = 0.24, SE = 0.12, p = .180, 95% CI [-0.07, 0.54].*

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Zero contingency conditions: The 3 (Stimulus Type: happy, sad, shape) × 2 (Strength: strong, weak) repeated-measures ANOVA did reveal a significant interaction between stimulus type and strength, $F\ (2, 88) = 4.15$, p $= .020$, η^2□ $= .046$, and a significant main effect of strength, $F\ (1, 89) = 41.77$, p $< .001$, η^2□ $= .327$, but the main effect of stimulus was not significant, $F\ (2, 88) = 1.61$, $p = .202$, η^2□ $= .018$. To understand the interaction, we examined the analysis broken down by strength and then analysed for stimulus effects. In the weak condition, the stimuli effect was not significant $F\ (2, 88) = .731$, $p = .483$, η^2□ $= .008$ but in the strong condition it was F $(1, 86) = 4.840$, $p = .009$, η^2□ $= .053$. Pairwise comparisons in the strong condition revealed that ratings for happy faces were more positive than shapes (MD = 0.66, SE = 0.18, $p = .002$, 95% CI [0.21, 1.11]), and sad faces (MD = 0.46, SE = 0.27, $p = .035$, 95% CI [0.041, 1.097]). The other pairwise comparison with sad and shape was not significant (p $\geq .200$, *95% CIs*), indicating that ratings for sad stimuli did not differ significantly from to shape stimuli. As illustrated in Figure 5, participants gave higher contingency ratings under strong conditions compared to weak conditions across all stimuli, but this effect was quantitively more pronounced for happy stimuli. These findings suggest that the influence of strength on contingency judgments was specifically modulated by the type of stimulus, with happy faces driving the interaction.

Negative contingency conditions: A 3 (Stimulus Type: happy, sad, shape) × 2 (Strength: strong, weak) repeated-measures ANOVA revealed again that participants consistently rated happy and shape stimuli more negatively than sad stimuli as the strength was changed from the weak to the strong. There was a statistically significant interaction between stimulus type and strength, $F\ (2, 88) = 3.56$, $p = .031$, η^2□ $= .040$, along with significant main effects of stimulus type, $F\ (2, 88) = 19.32$, $p < .001$, η^2□ $= .183$, and strength, $F\ (1, 88) = 161.20$, $p < .001$, η^2□ $= .652$. To understand the interaction, we examined the analysis broken down by

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strength and then analysed for stimulus effects. In the weak condition, there was no significant effect of stimulus type, *F (2, 88) = 2.33, p = .101,* η^2_p *= .026*. In the strong condition, however, the stimulus effect was significant, *F (2, 86) = 24.32, p < .001,* η^2_p *= .220*. Pairwise comparisons showed that ratings for sad stimuli were significantly less negative than both happy *(MD = 1.09, SE = 0.20, p < .001, 95% CI [0.60, 1.58])* and shape stimuli *(MD = 1.08, SE = 0.19, p < .001, 95% CI [0.62, 1.53])*, while ratings for shape and happy stimuli did not differ *(MD = 0.02, SE = 0.15, p = 1.000, 95% CI [−0.34, 0.37]).*

--- Insert Figure 6 about here ---

Planned Contrasts for Testing Pairing Hypothesis

To investigate the effects of cue–outcome pairings we conducted four planned contrasts focusing on two sets of conditions with equal numbers of cue–outcome pairings: strong positive (7 pairings) versus strong zero (7 pairings), and weak zero (1 pairing) versus strong negative (1 pairing), for this comparison the question is whether equivalent pairings result in different ratings as predicted by the overall contingency. Additionally, there were two set of conditions with unequal pairings that pit contingency and pairings more directly, according to a pairing related effect, the weak positive condition with 5 pairings might be expected to elicit weaker ratings than strong zero on the basis of pairings (i.e., 7 pairings) but stronger ratings on the basis of the overall contingency. Similarly, the weak negative (3 pairings) and weak zero contingency (1 pairing) set up opposite expectations from the two explanations (contingency vs pairing). Each contrast was tested across three stimulus types (happy, sad, shape), resulting in designs of [contingency × stimulus].

For the strong positive (7 pairings) versus strong zero (7 pairing) contrast, there was a significant stimulus × contingency interaction, *F (2, 172) = 7.45, p <.001,* η^2_p *= .080*, and

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main effect for contingency, $F\ (1, 86) = 325.39,\ p < .001,\ \eta^2_p = .791$, with higher ratings in the strong positive condition, as well as a stimulus effect, $F\ (2, 172) = 16.18,\ p < .001,\ \eta^2_p = .158$. Pairwise comparisons for each pair of happy, sad and shape demonstrated similar significant effects of contingency (all comparisons min $F= 55.715,\ max\ p< .001$) suggesting that contingency rather than pairings determined the ratings.

Similarly, the weak zero versus strong negative contrast showed a significant stimulus × strength interaction, $F\ (2, 172) = 6.03,\ p = .003,\ \eta^2_p = .066$, as well as a main effect for contingency, $F\ (1, 86) = 322.26,\ p < .001,\ \eta^2_p = .789$, with more positive ratings in the weak zero condition compared with strong negative condition even though both had the same number of pairings. The main effect for stimulus was also reliable, $F\ (2, 172) = 18.15,\ p < .001,\ \eta^2_p = .174$. As with the previous analysis the effect of contingency was significant for each stimulus type (all comparisons min $F= 72.307,\ max\ p< .001$).

The second set of comparisons examined the pairing hypothesis that contrasted conditions with fewer pairings in the conditions with stronger contingency, the weak positive versus strong zero contrast revealed a significant contingency × stimulus interaction, $F\ (2, 88) = 3.70,\ p = .027,\ \eta^2_p = .041$, and both main effects were significant for contingency, $F\ (1, 86) = 66.95,\ p < .001,\ \eta^2_p = .438$, with higher ratings in the weak positive condition, and stimulus type, $F\ (2, 88) = 14.06,\ p < .001,\ \eta^2_p = .140$. Again, for each stimulus type the contingency effect was significant (all comparisons min $F= 4.697,\ max\ p= .033$).

Finally, the weak negative versus weak zero contrast revealed no significant Stimulus × Contingency interaction, $F\ (2, 172) = 0.38,\ p = .685,\ \eta^2_p = .004$, but a significant main effect of contingency was observed, $F\ (1, 86) = 61.07,\ p < .001,\ \eta^2_p = .415$, with higher ratings in the weak zero condition in spite of the fact that this condition had fewer pairings

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than weak negative. In this case the main effect of stimulus type was not significant, $F(2, 172) = 2.45, p = .089, \eta^2_p = .028$.

Overall, these results clearly and perhaps exhaustively confirm that differences in the emotive contingency judgments cannot be explained purely by the frequency of the two similar facial expressions (A events) but reflect a complex judgement that is sensitive to contingency and was present with both faces and shapes.

Experiment 3 was designed to test how different emotional expressions influence contingency sensitivity using weak and strong strengths in positive, zero, and negative contingencies. The results demonstrated that participants were able to discriminate contingencies as well as the changes in contingency strength. Consistent with Experiment 1 and 2, participants' judgments were influenced by emotional information. There was only limited evidence that happy faces were learned more easily than shapes, but there was consistent evidence that sad produced weaker discrimination between contingencies.

Our findings are consistent with previous research that highlights an advantage for happy faces in attention and learning tasks (Calvo & Nummenmaa, 2008; Evans et al., 2010; Saylik et al., 2021; Yuan et al., 2023) compared with aversive expressions, however given the evidence with shapes it is perhaps more consistent to suggest that sad faces impair learning. In the final experiment, we aimed to test whether the weaker effect for sad faces is generalizable to other expressions that characterise negative valence (as opposed to negative contingency), here we explored fear and anger.

Experiment 4

Experiment 4 tested two other negatively valenced expressions: fear and anger. Evidence suggests that sadness shares arousal characteristics with other emotional expressions stimuli (Kim et al., 2019). For instance, cortical heartbeat processing during perception of sad faces

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is similar to the perception of angry and fearful faces, which are distinct from happy faces in emotion recognition tasks (Beaurenaut et al., 2023; Kim et al., Maister et al., 2017). Consequently, we might anticipate similar interference with causal perception from anger and fear as observed with sadness. The interference in causal perception may be attributed to the fact that sad facial expressions signal negativity that induces worry-related arousal (Dolcos & McCarthy, 2006; Mancini et al., 2022; Saylik & Szameitat, 2018; Xie et al., 2023). This worry-related arousal has been argued to interfere with or create scarcity in attentional resource allocation.

We hypothesised that, if learning is influenced by the saliency of stimuli, then angry and fearful faces may be learned about similarly to happy faces. This hypothesis suggests that sad perhaps is simply differentially salient and an anomaly. On the other hand, if learning is influenced by emotional content and its valence, then angry and fearful faces may be judged to be less contingent than happy faces much like responding to sad faces in Experiments 1-3.

Methods

Participants

In accordance with the exclusion criteria, 7 participants (4 females: M = 19.75, SD = 1.25; 3 males: M = 23.66, SD = 4.50) out of 58 were excluded due to either a history of depression or anxiety, or high scores on the Beck Depression Inventory (BDI). The final sample consisted of 51 healthy university participants (26 Male, 25 Female) aged between 19-35 (males: M = 23.87 years, SD = 3.35; females: 22.40, SD = 3.72). The task, materials and procedure used in this study were matched to those of emotional tasks in Experiment 1. Given the reduction in number of conditions in comparison to Experiment 3 and the medium size effects for the stimulus effect comparing Sad with Happy, we reduced the recruitment sample size based on a new power analysis (Murphy et al., 2022; Murphy & Castiello, 2024).

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Results and discussion

As shown by ratings in Figure 7, participants judged the three contingencies in line with their statistical relation. Consistent with the previous findings, happy faces were judged more contingent than those with angry and fearful faces. We performed 3x3 factorial ANOVA; Stimulus (i.e., (happy, angry, fearful) x Contingency (positive, zero, negative). The ANOVA results revealed a significant interaction effect *[F (4, 47) = 3.864, p= .005, η2= .080]* as well as the main effect for contingency *[F (2, 49) = 177.323, p< .001, η2= .798]* but not for stimulus *[F (2, 49) = 0.653, p= .357, η2= .008]*. The mean differences for these pairwise comparisons for positive vs zero and zero vs negative respectively were all consistent with the previous experiments for happy (MDs = 3.17, 2.52), angry (MDs = 2.50, 1.52), and fearful (MDs = 2.52, 1.65), all significant (all ps < .001).

Contingency-Specific Findings

We conducted a stimulus analysis for each contingency. The Positive contingency conditions: A 3 (Stimulus Type: happy, fearful, angry) repeated-measures ANOVA revealed a significant effect between stimuli *F (2, 49) = 6.10,* p= *.003, η²*□ *= .119*. Post hoc pairwise comparisons revealed that happy stimuli were rated significantly more positively than both angry, *MD = 0.80, SE = 0.27, p = .015, 95% CI [0.13, 1.48]*, and fear, *MD = 0.87, SE = 0.28, p = .011, 95% CI [0.17, 1.57]*. There was no significant difference between angry and fear stimuli, *MD = 0.07, SE = 0.28, p = 1.000, 95% CI [-0.62, 0.75]*.

Zero contingency conditions: A 3 (Stimulus Type: happy, fearful, angry) repeated-measures ANOVA revealed a non-significant effect of stimulus type, F*(2, 49) = 1.66,* p *= .847, η²*□ *= .003*, indicating as with the results from E1 and E2 that ratings did not differ across stimulus types in the zero-contingency condition.

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Negative contingency conditions: A 3 (Stimulus Type: happy, fearful, angry) repeated-measures ANOVA revealed a significant difference between stimuli F *(2, 49) = 3.88,* p= *.024,* η^2_p *= .079*. Post hoc pairwise comparisons revealed that happy stimuli were rated significantly more negatively than both angry, *MD = -0.87, SE = 0.33, p = .034, 95% CI [-1.69, -0.05]*, and fear, *MD = -0.74, SE = 0.29, p = .043, 95% CI [-1.46, -0.02]*. However, no significant difference was found between angry and fear stimuli, *MD = 0.13, SE = 0.36, p = 1.000, 95% CI [-0.76, 1.02]*. Altogether, the results indicated that threatening faces (fearful/angry) generally lead to a weaker perception of causality than happy faces.

Experiment 4 demonstrated that participants judged angry and fearful faces less contingent than happy faces in positive and negative contingencies. Zero contingencies showed no differences. The results are clearly consistent with previous three experiments that highlights some disadvantage for aversive expressions including sad, angry, and fearful. Therefore, our results suggest that this effect more likely to be due to influence of emotion on contingency learning rather than similarity effects between sad and neutral faces.

Although our instructions clearly emphasized predictability, and prior research supports this (Allan et al., 2008; Murphy et al., 2022), the similarity between sad faces and neutral faces may have influenced the results. However, in Experiment 4, we replaced sad faces with angry and fearful faces, aligning with the methodology used in Experiments 1 and 2. If the findings in Experiments 1 and 2 were driven by the similarity between sad and neutral faces—potentially because sad faces are less salient than happy faces—then the results from Experiment 4 should differ. This is because angry faces, widely regarded as highly salient and distinct from neutral faces, would not be expected to produce similar outcomes as sad faces in the earlier experiments. Therefore, we propose that the observed results are more

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easily explained by the influence of emotional content on contingency learning, rather than by any similarity effect between neutral and emotional faces.

--- Insert Figure 7 about here ---

General Discussion

Four experiments examined how faces containing emotional content influence the ability to learn the contingent expressions of faces. We showed that all contingencies were discriminable (Allan et al., 2008; Crump et al., 2007; Heisz et al., 2011). Further, positive ($\Delta P + .50$) and negative contingencies ($\Delta P\ -.50$) with sad faces were consistently perceived to be less contingent compared to happy faces and shapes and likewise there was a trend indicating shapes were also judged to be less contingent in positive contingencies than happy faces, but this effect was not consistent across Experiments 1-3. Moreover, we demonstrated that as the delta p (negative contingencies) and probability (zero contingency) were varied from weak to strong, the interfering effect of sad faces became more pronounced (Experiment 3) which demonstrates that participants were learning the overall contingency rather than relying on the number of times the same facial expressions were presented in both faces. We also confirmed that the effect on impaired perception of contingency is not unique to sad faces but is also evident when comparing angry and fearful expressions to happy ones (Experiment 4).

We interpret our findings to suggest that emotional content influences contingency learning: aversive expressions appear to weaken the perception of causal outcomes, while happy faces may support this process relative to aversive expressions. However, this effect does not necessarily indicate that happy faces enhance causal perception overall. The advantage of happy faces over shapes was not consistent, appearing only under specific conditions: in Experiment 1, during the positive contingency condition ($\Delta P = 0.50$), and in Experiment 3,

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during the zero contingency condition (outcome probability = 0.875). Previous research on the effects of emotional stimuli on attention and learning highlights an advantage for happy faces enhance attentional orientation (Calvo & Nummenmaa, 2008; Yuan et al., 2023), as they are rewarding, pleasant, and facilitate the formation of associations (Evans et al., 2010; Saylik et al., 2025). For instance, previously it has been shown that participants are inclined to establish associations with happy faces even if they are paired with negative stimuli (Fulcher et al., 2001) or followed by lower valued outcomes (Averbeck & Duchaine, 2009; Evans et al., 2010) suggesting some associative transfer of emotional content. However, the majority of previous research testing the effect of emotional expression maintain a set of emotional stimuli (e.g., Happy, Angry) rather than using control conditions consisting of non-emotional stimuli (e.g., objects, shapes; e.g., Averbeck & Duchaine, 2009; Calvo et al., 2006; Evans et al., 2010)**.** Nevertheless, our findings confirm an advantage of happy in learning over aversive expressions but considering the limited superiority of happy faces over shapes, and distinctive disadvantages of aversive expressions comparing to both happy and shape stimuli, we rather prefer to highlight those aversive expressions impair perception of causal outcomes.

We can speculate as to the reasons why aversive faces have a deleterious effect on learning. We have discussed how the actual physical characteristics of the faces might have an impact on learning. An alternative perspective might reflect on the previous predictability of different facial expressions. The associability of a cue, the ability for a cue to be learned, is determined by both its physical properties as well as its previous predictive validity (Mackintosh, 1976; Le Pelley, 2010).

One theory that has been recruited to explain human contingency learning of uncertain probabilistic relations was proposed by Mackintosh (1975). A theory of selective attention,

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Mackintosh suggested that the extent to which a stimulus is processed depends on its physical or perceptual salience and its reliability as a predictor of outcomes. The theory relies on two principles that (a) we learn contingencies by attending to task relevant cues while ignoring task irrelevant ones and (b) more salient cues draw more attention and are learnt easier than other cues (see also Aisbitt & Murphy, 2016). To assess the relevance of associability, we might conclude that, based on previous experience, happy expressions are more reliable indicators of their causal consequences than aversive expressions. Specifically, happy faces may more reliably elicit happy expressions in others compared to the effect of aversive expressions. However, this hypothesis still needs to be tested.

Considering that salient stimuli enhance learning contingent events; all emotional stimuli might have reasonably been expected to contribute to the perception of the contingencies more easily compared to non-emotional stimuli. First, while sad faces may be less salient than happy faces, they are expected to be more salient than neutral stimuli (e.g., shapes) (Calvo et al., 2018; Yuan et al., 2023). However, we did not find this effect. Second, the impaired perception of causal outcomes was evident not only with sad faces but also with angry and fearful ones. Research suggests that the saliency of happy and threatening faces are comparable because many studies indicate that threatening faces (e.g., angry faces) are among the most salient emotional expressions (Barros et al., 2023; Lundqvist et al., 2014). Similar evidence has been reported for happy faces (Calvo & Nummenmaa, 2008; Stuit et al., 2023; Yuan et al., 2023). The primary distinction between happy and negative/threatening emotional expressions lies in their content: positive/pleasant versus negative/aversive. Therefore, other factors may interact with salience and influence the learning process, contributing to the differences in judgment across emotional stimuli, both the stimuli content and format of presentation have been shown to play a role in determining the absolute judgements in contingency tasks (Vallee-Tourangeau, Payton and Murphy, 2008).

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Our interpretation does not rule out the possibility that aversive stimuli have higher perceptual salience (e.g., angry and fearful; Elsherif et al., 2017). Aversive emotional stimuli may be processed more quickly via a selective attention mechanism(Calvo et al., 2006; Öhman et al., 2010; Öhman & Mineka, 2001; Pinkham et al., 2010). However, unlike happy faces, aversive faces are associated with threat and danger, contributing to their negative psychological saliency in addition to their physical saliency (Fischer & Manstead, 2008; Öhman & Mineka, 2001). Although the aversive or threatening nature of these faces is rapidly detected by selective attention, they may disrupt other attentional processes—such as sustained attention—by triggering arousal and task-irrelevant mental activity, thereby depleting the cognitive resources needed for task-relevant processing (Dolcos & McCarthy, 2006; Mancini et al., 2022; Saylik, 2017; Saylik et al., 2025; Xie et al., 2023).

Another potential explanation for differences in causal perception between aversive and happy expressions involves both physical and psychological saliency. Learning theories suggest that salient stimuli—whether due to visual prominence or emotional relevance — enhance a stimulus's predictive ability, making it more likely to be associated with outcomes (Mackintosh, 1975; Pearce & Mackintosh, 2010b). Emotional faces, for example, are often both psychologically and perceptually salient, directing attention and facilitating associative learning (Le Pelley et al., 2010, 2016; Mackintosh, 1975; Pearce & Mackintosh, 2010b). Psychological factors such as desirability, pleasantness, and mood further influence this process (Matute et al., 2019). In this context, happy faces are the only positive basic emotion and are frequently encountered, making them both physically and psychologically more distinctive (Barros et al., 2023). Their visual salience with positive emotional value—reflected in higher contrast across tasks and analytic methods—may enhance their perceived predictive value, leading to stronger causal judgments (Calvo et al., 2016, 2017, 2018; Calvo & Marrero, 2009; Calvo & Nummenmaa, 2008; Stuit et al., 2023). In contrast, aversive

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expressions (e.g., sadness, anger) may signal threat or discomfort, diminishing their perceived reliability as predictors in social contexts. This may explain why neurotypical participants perceive stronger causal links when exposed to happy rather than to aversive facial cues (Averbeck & Duchaine, 2009; Saylik et al., 2025).

Finally, consistent differences in judgments were observed between positive and negative contingencies. In three experiments (1, 2, and 4), the outcome densities were equal across all conditions (positive, zero, and negative contingencies), but cue-outcome pairs (cell a) were significantly higher in the zero-contingency compared to the negative contingency. Negative contingencies themselves may be more difficult to learn or have specific impacts on learning (Vallee-Tourangeaau, Murphy & Baker, 1998) not predicted by the simple strength of correlation. The stimulus effect in contingency judgment processing we observed are not solely driven by emotional expression, it is also driven by statistical changes in the task (see also Vallee-Tourangeau et al, 1998).

The current study has some limitations that should be considered for future research. First, although we aimed to balance the perceptual demands of shapes (control tasks) and faces in Experiments 2 and 3, few concerns may still arise due to the inherent differences between non-emotional and emotional stimuli. We utilized the streaming procedure proposed by Allan (2008). Previous studies (Allan et al., 2008; Heisz et al., 2011) found no significant difference in learning between emotional and non-emotional stimuli. Although a few studies have combined emotional and non-emotional objects (e.g., Lego and animal images) (He et al., 2013) in associative learning tasks or visual search tasks (e.g., faces, scenes)(Kunar et al., 2014), those tasks were not identical to ours. To test this within the context of causal learning, it was necessary to compare the judgment ratings across contingencies that include these two types of stimuli by taking non-emotional stimuli as control tasks. Therefore, the

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shapes provide a baseline effect with stimuli of the same size and duration. It is true that the absence of detail in the shapes might have made them more difficult to perceive, but presumably not more difficult than the sad condition, which elicited less strong ratings. Or the absence of detail in the shapes might have made them easier to learn, but again if the absence of detail was relevant for learning, then we might have expected them to generate stronger ratings than the happy condition. As a baseline comparison of stimuli of the same size and duration and contingency, the shapes provide a form of non-perfect but useful comparison. Nevertheless, future studies could consider using different images that fall within the same category. Second, in the current research, our assessments were mainly based on participants' ratings rather than response times. Further inquiry could explore how further probabilistic variations might reveal the source of privileged attentional allocation to aversive/threatening expressions (angry, fearful), incorporating emotional densities as well as speed and accuracy measures. This could help enhance our understanding of disruptions in the perception of others' emotional states or mental health in response to threatening stimuli (e.g., depression, Chase et al., 2011).

To conclude, conversational expressions that unfold over time (i.e., emotive contingencies) may offer valuable predictive information that supports the understanding of emotional dynamics. Participants in our studies were able to learn associations between facial expressions. We also suggested that aversive facial stimuli could impair the perception of causal relationships when assessing predictiveness in contingency discrimination. If we assume that our happy and aversive emotional stimuli (i.e., sad, angry, fearful) were of similar physical salience (as evidenced by the reliability of Radboud stimuli), then another factor—such as positive and negative psychological salience driven by emotional content—may hinder aversive expressions and favour happy facial expressions in predictive learning.

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In this sense, emotive contingencies play a crucial role in sustaining social understanding or providing cues for social disintegration.

Declarations of interest

We have no conflicting interest. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authorship contribution statement

Rahmi Saylik: Conceptualization, Investigation, Software, Data curation, Formal analysis, Methodology, Writing the original draft, Visualization. Andre J. Szameitat: Software, Writing - review & editing, Visualization. Adrian L. Williams: Formal Analysis, Review & editing, Visualization. Robin A. Murphy: Software, Formal analysis, Investigation; Methodology, Writing, review & editing, Visualization.

Data Accessibility Statement

The data and materials from the present experiment are publicly available at https://doi.org/10.6084/m9.figshare.28162817.v1 . Data, were analyzed using SPSS, version 25 without pre-registration but the primary theories regarding statistical learning are derived from existing associative theory regarding contingency learning (Murphy et al., 2017).

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Figure Captions

Figure 1. Panel (a) shows the four possible cue-outcome pairs of streamed trials with happy faces. Panel (b) shows an example for rapid presentation of happy and neutral faces in the streaming trial procedure.

Figure 2. (a) shows four possible cue-outcome pairs of a streamed trial. (b) shows an example for rapid presentation of shapes in the streaming trial procedure. Each stream condition consisted of 60 trials.

Figure 3. Panel A presents the mean contingency judgements for each contingency (negative, zero and positive) and stimulus types (happy, sad and shapes) in Experiment 1 Panel A and Experiment 2 Panel B. Error bars indicate indicates 95% confidence interval (CI).

Figure 4. Panel (a) illustrates an example of four possible **cue-outcome pairs a (both cue and outcome are presented, b (Cue is present but outcome is absent), c (Cue is absent but outcome is present), d (Both cue and outcome are absent)** in a streamed trial for the **non-emotional conditions**. Panel (b) provides an example of the **rapid presentation of patterned shapes** in the **streaming trial condition**.

Figure 5. Panel (a) shows the four possible cue-outcome pairs ***a (both cue and outcome are presented, b (Cue is present but outcome is absent), c (Cue is absent but outcome is present), d (Both cue and outcome are absent***) of streamed trials with sad faces. Panel (b) shows an example for rapid presentation of sad and neutral faces in the streaming trial procedure.

Figure 6. shows participants mean contingency judgements along with weak and strong contingency strengths in each negative, and positive contingency conditions and stimulus types (shapes, sad and happy faces. For zero contingencies, a probability of 0.125 indicates a weak strength, while a probability of 0.875 indicates a strong strength. Above each contingency types of number of 'a' trials were indicated. Error bars indicate indicates 95% confidence interval (CI).

Figure 7. shows participants mean contingency judgements along with contingency frequencies (negative, zero and positive) and stimulus types (happy, angry and fearful). Error bars indicate indicates 95% confidence interval (CI).

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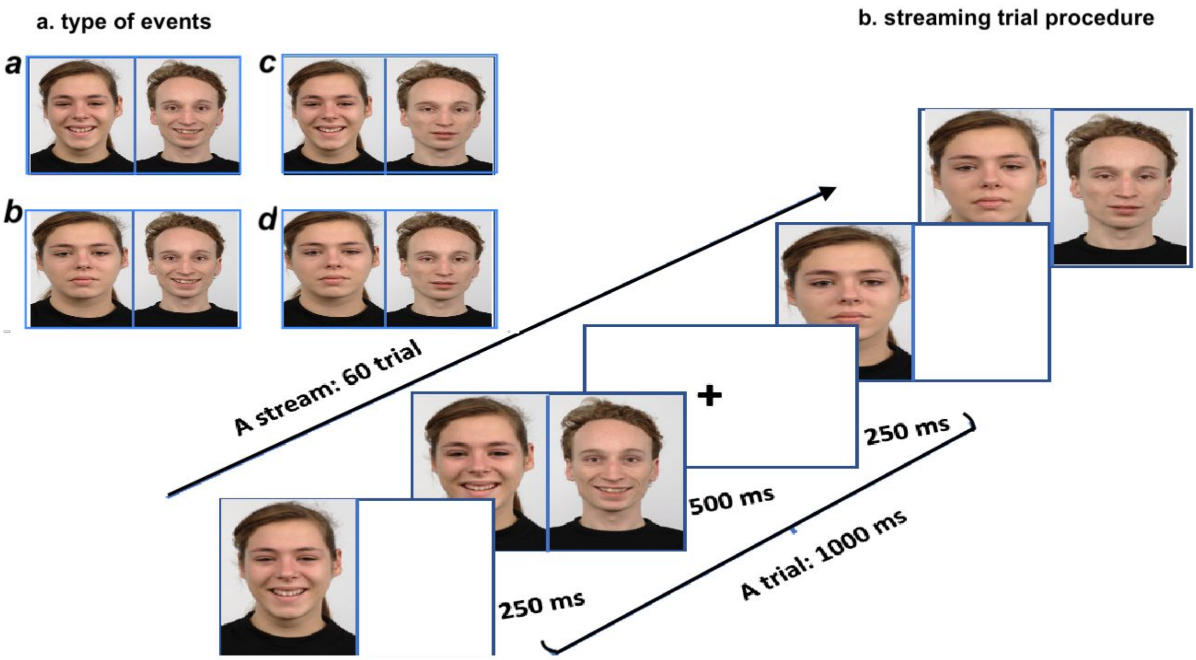

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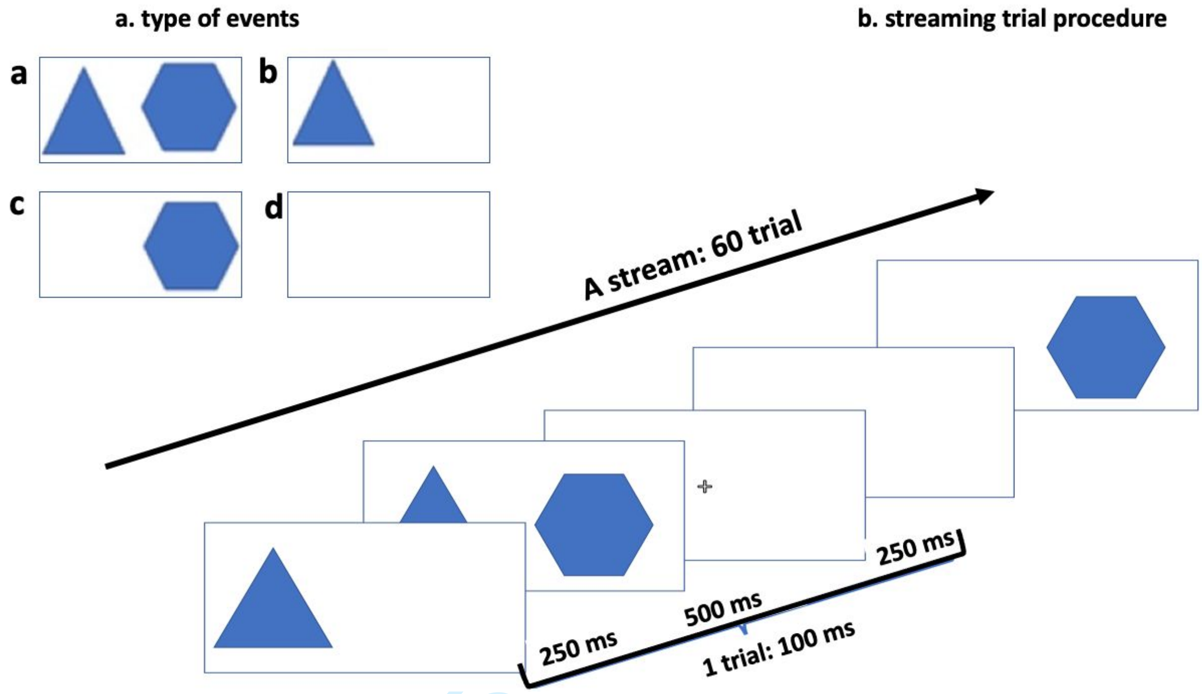

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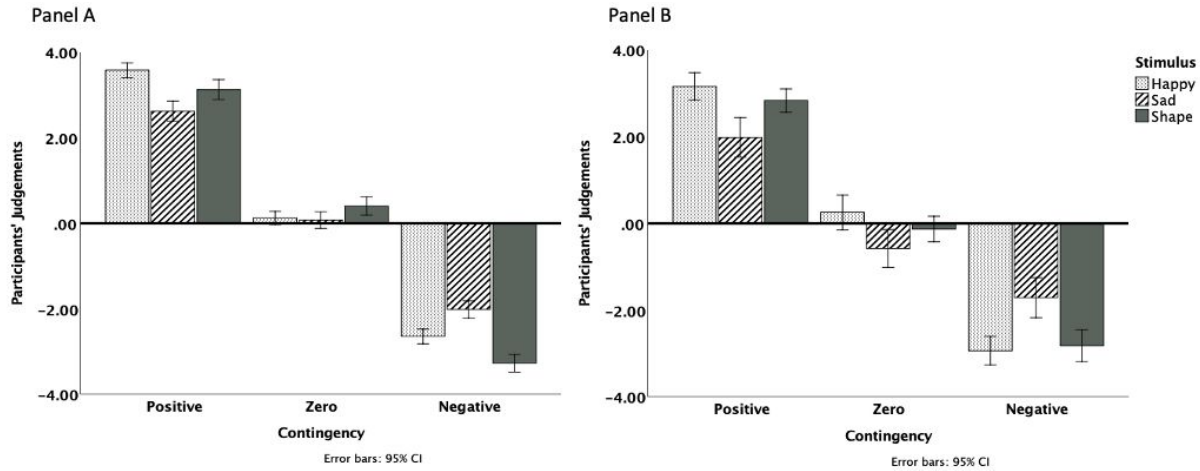

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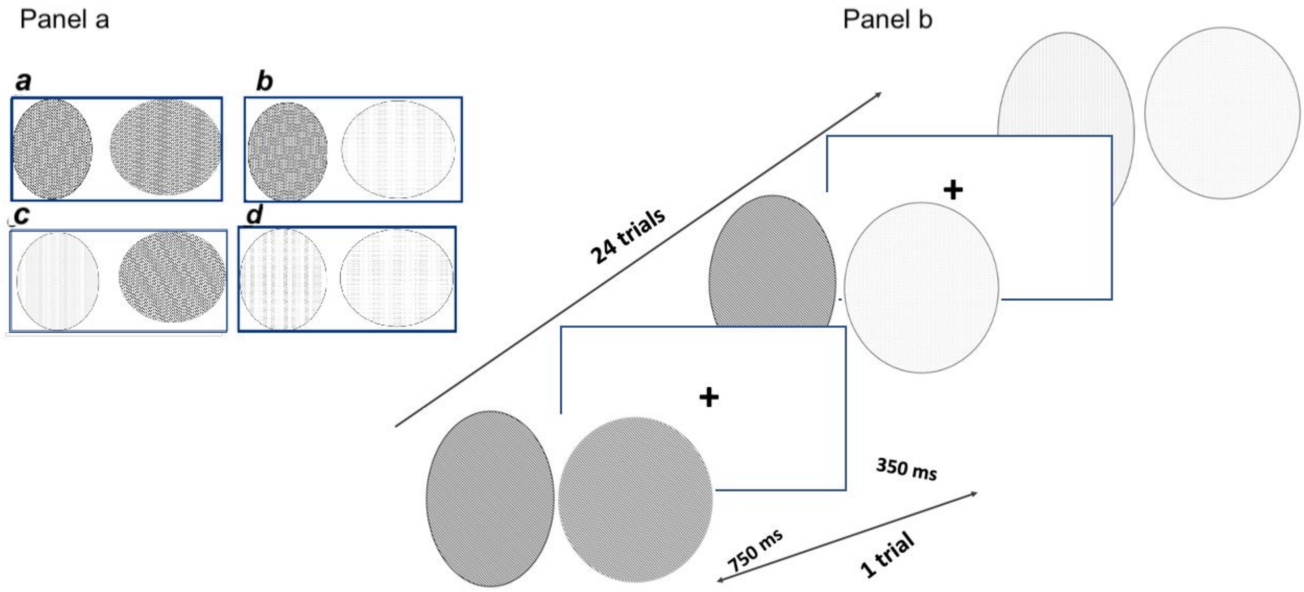

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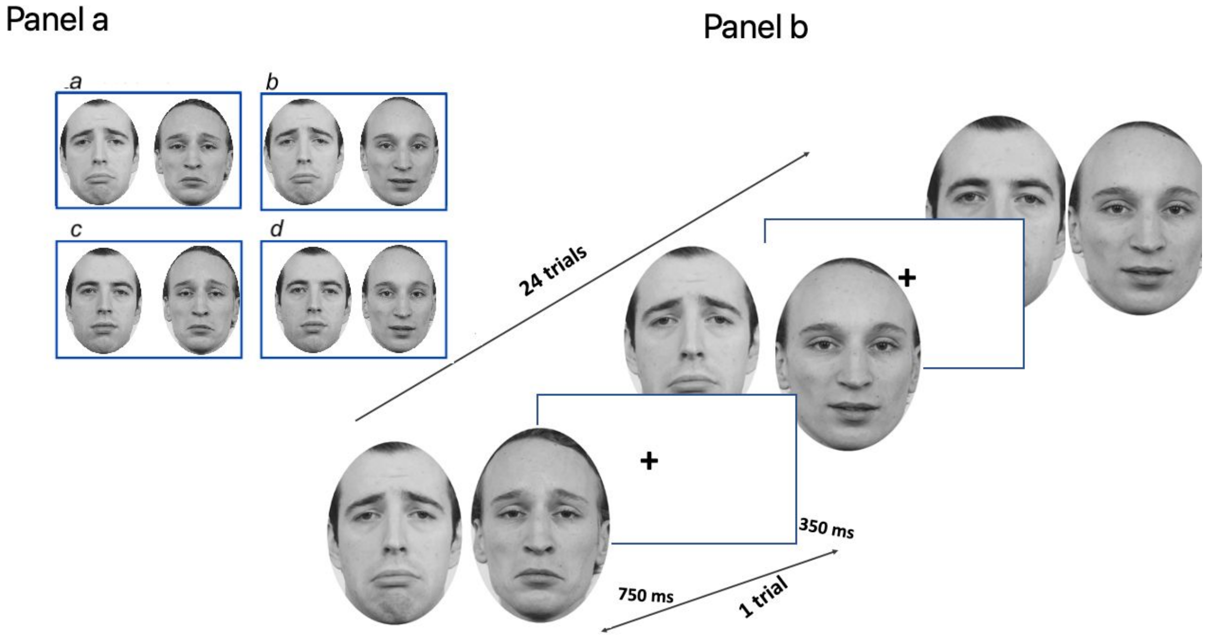

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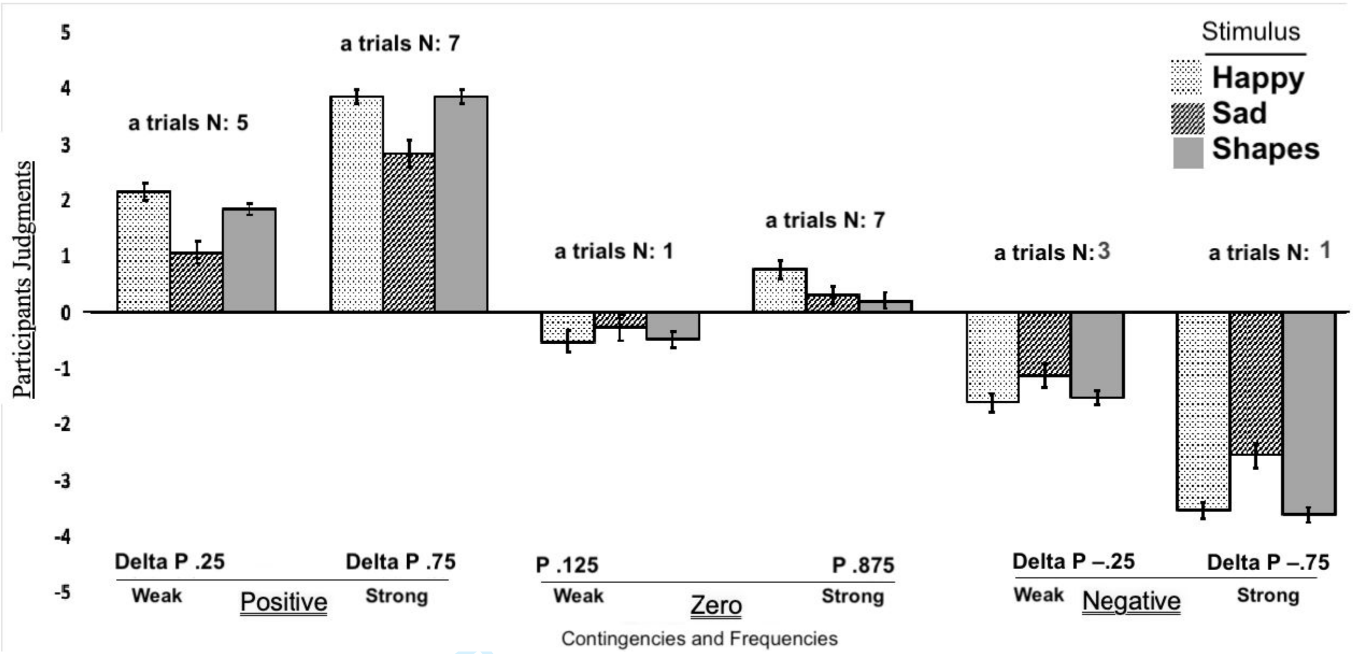

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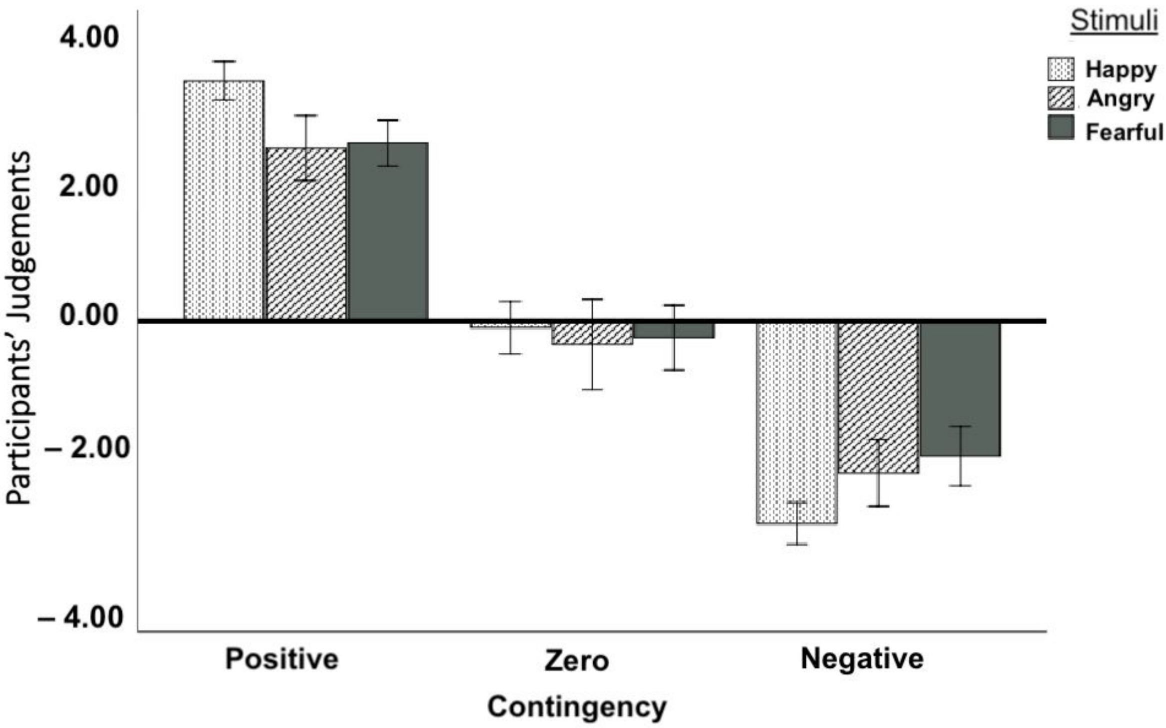

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Table 1. The distribution of trials for each cell 'a= Cue (+C) and Outcome (+O), b= C+ and No Outcome (–O), c= No Cue (–C), and +O, d= –C and –O along with statistical relations for conditional probability (P of O) and Delta P (*Δ*P) in Experiment 1.

POSITIVE				ZERO				NEGATIVE			
	O+	O–	P		O+	O–	P		O+	O–	P
C+	22	7	0.76	C+	15	15	0,5	C+	8	23	0.26
C–	8	23	0.26	C–	15	15	0,5	C–	22	7	0.76
Sum of +O	30		*Δ*P	Sum of +O	30		*Δ*P	Sum of +O	30		*Δ*P
			0,5				0				-0,5

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Table 2 shows distribution of trials in each along with statistical relations for probability (P) and Delta P (ΔP) in Experiment 2.

POSITIVE				ZERO				NEGATIVE			
	O+	O–	P		O+	O–	P		O+	O–	P
C+	9	3	0,75	C+	6	6	0,5	C+	3	9	0,25
C–	3	9	0,25	C–	6	6	0,5	C–	9	3	0,75
Sum of +O	12		ΔP	Sum of +O	12		ΔP	Sum of +O	12		ΔP
			0,5				0				-0,5

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Table 3. shows the distribution of trials in each cell ('a' = Cue (+C) and Outcome (+O), 'b' = +C and No Outcome (~O), 'c' = No Cue (~C) and +O, 'd' = ~C and ~O) along with statistical relations for probability (P) and Delta P (ΔP) in the conditions with strong and weak.

Frequencies		**POSITIVE**				**ZERO**				**NEGATIVE**		
High		O+	O−	P		O+	O−	P		O+	O−	P
	C+	7	1	0.875	C+	7	1	0.875	C+	1	7	0.
	C−	1	7	0.125	C−	7	1	0.875	C−	7	1	0.
	Sum of +O	8		ΔP	Sum of +O	14		ΔP	Sum of +O	8		
				0.75				0				−
		POSITIVE				**ZERO**				**NEGATIVE**		
		O+	O−	P		O+	O−	P		O+	O−	
Low	C+	5	3	0.625	C+	1	7	0.125	C+	3	5	0.
	C−	3	5	0.375	C−	1	7	0.125	C−	5	3	0.
	Sum of +O	8		ΔP	Sum of +O	2		ΔP	Sum of +O	8		
				0.25				0				−

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