anales de psicología / annals of psychology
2022, vol. 38, nº 2 (may), 375-381
https://doi.org/10.6018/analesps.408801

ISSN print: 0212-9728. ISSN online: 1695-2294.
https://revistas.um.es/analesps

Detecting facial expressions within a context of surprise and uncertainty

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Título: Detectando caras en un contexto de sorpresa e incertidumbre.
Resumen: Las expresiones de amenaza son detectadas con rapidez y precisión, advirtiendo a quienes las observan de la presencia de un potencial peligro. Durante el proceso de detección, la expresión de sorpresa podría jugar un papel importante como clave de orientación en condiciones de incertidumbre donde se requiere una respuesta rápida y precisa. Con el objetivo de analizar este supuesto se plateó un experimento en el que participaron 70 sujetos que realizaron una tarea de señalización espacial, donde se utilizaron expresiones faciales de sorpresa (vs. neutra) como claves de orientación, y expresiones faciales de miedo, ira, alegría y neutras como estímulos objetivo. Los resultados mostraron un efecto facilitador de la expresión de sorpresa solo en la detección de la expresión de ira, reduciendo los tiempos de respuesta y el porcentaje de errores. Los datos apuntan a que la expresión de sorpresa, cuando se procesa como un estímulo independiente, podría facilitar la detección de aquellos estímulos que supongan una amenaza directa, como la expresión de ira, siendo esta distinción clave para entender en qué condiciones se detecta más eficazmente la expresión de ira respecto a otro tipo de expresiones.
Palabras clave: Expresiones faciales emocionales. Neutra. Ira. Sorpresa. Miedo. Tarea de señalización espacial.

Abstract: Threatening expressions are detected quickly and accurately, warning the observer of the presence of a potential danger. During the detection process, a facial expression of surprise could play an important role as a cue for orientation in conditions of uncertainty that call for a swift and precise response. With a view to analysing this contingency, an experiment was conducted in which 70 subjects undertook a spatial cueing task that involved facial expressions of surprise (vs. neutral ones) as orientation cues, and facial expressions of fear, anger and happiness as target stimuli. The results revealed a priming effect of the expression of surprise solely in the detection of the expression of anger, reducing response times and the percentage of errors. The data indicate that the expression of surprise, when processed as an independent stimulus, could prime the detection of those stimuli that constitute a direct threat, such as the expression of anger, with this being a crucial distinction for understanding the circumstances in which the expression of anger is detected more effectively than other kinds of expressions.
Keywords: Emotional facial expressions. Neutral. Anger. Surprise. Fear. Spatial cueing task.

Introduction

Facial expressions have an important role to play as a channel for conveying information within a social setting (Frith, 2009), above all when this information is necessary for survival, warning of contextual aspects that would be difficult to transmit more effectively by other means. Facial information is therefore processed by a specialised neuronal network (see Gordillo et al., 2017). It is vital for human beings to be able to detect signals that warn of the presence of a threat in situations in which the danger stimulus might appear in an unheralded and unpredictable manner. Within this context, expressions of fear and anger will alert an observer to the presence of a potential danger, and thereby prioritise their processing (*The threat hypothesis*; Calvo et al., 2006; Fox et al., 2000), especially regarding the eye area (Fox and Damjanovic, 2006).

Although expressions of fear and anger are considered threatening, they need to be differentiated in certain aspects. Firstly, regarding the brain structures involved in their perception, while facial expressions of anger trigger the greater activation of prefrontal structures, such as the Ventrolateral Prefrontal Cortex (VLPFC), the expression of fear involves structures such as the amygdala and entorhinal cortex (Lindquist et al., 2012). Secondly, the expression of anger warns of a direct threat from the person emitting it, while the expression of fear involves a threat present in the environment (De Valk et al., 2015; Juncai et al., 2017; Wilson and MacLeod, 2003). The expression of anger, therefore, prompts a phobic response in the onlooker, at the same level, for example, as a snake would, without requiring a conscious representation of the stimulus (Öhman and Soares, 1993). The importance of detecting the direct threat posed by the facial expression of anger has been reported in various studies, which have found that it is processed more effectively than other kinds of expressions. For example, in tasks requiring participants to detect the discrepancy between two expressions that appear at the same time (Horstmann and Bauland, 2006; Fox et al., 2000); in tasks for detecting facial expressions in a crowd (e.g., Calvo et al., 2006; Hansen and Hansen, 1988; Krysko and Rutherford, 2009; Öhman et al., 2001; Pinkham et al., 2010), and in dot-probe-type tasks (Mogg and Bradley, 1999; Wirth and Wentura, 2019).

In turn, the expression of surprise is not considered a threatening stimulus, although it might play an important part in the processes of detecting those expressions that alert to a possible danger. Surprise triggers two different stages in the onlooker; an initial one in which the individual stops what they are thinking and doing, and a second one in which an affective valence (positive or negative) arises once the cause of the surprise has been identified (Noordewier and Dijk, 2018). It is therefore to be expected that the perception

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(Article received: 03-01-2020; reviewed: 02-04-2021; accepted: 08-02-2022)

of an expression of surprise will lead to an initial hiatus in the onlooker, followed by the search for the stimulus that has triggered that emotion. Some studies have found that the expression of surprise has a priming effect on the identification of the expression of fear, which is not the case with other kinds of emotions (Gordillo et al., 2018, 2019). These findings are explained by the similarities in the muscle movements that constitute the expressions of surprise and fear, which are facilitating the priming effect (Gordillo et al., 2018, 2019), and which were explained in theory by the assumption that surprise and fear (as well as disgust and anger) are part of the same emotional category (Jack et al., 2014, 2016). Nevertheless, what effect will the expression of surprise have as an orientation cue on the detection of threatening facial expressions?

To answer this question, and as mentioned earlier, we need to remember that the expression of anger alerts to a direct threat originating in the actual individual producing the expression, while the expression of fear warns of a potential danger in the environment. Therefore, in a situation in which an individual is preactivated to a certain level (prior presentation of an expression of surprise), priority will be given to the detection of the stimulus that determines the more direct threat (expression of anger). Along these lines, certain studies report that the threat levels perceived in the expressions of anger and fear are modulated by the direction of the gaze, increasing in the expression of anger when the eyes focus on the onlooker, and doing the same in the expression of fear when they do not focus on (avoid) the onlooker (indicating the location of the possible danger in the environment) (Ewbank et al., 2009; O'Haire, 2011).

The spatial cueing task (Posner and Peterson, 1990) allows simulating a situation of surprise and uncertainty in which this assumption can be verified. Different studies have used these kinds of tasks to explore the effects of facial expressions as orientation cues. They have found that they reduce or increase the response times (RTs) of valid and invalid trials, respectively (Sawada and Sato, 2015). Other studies have found that the emotional facial expression as orientation cue caused changes in certain brainwaves that could be reflecting the neurocognitive sensitivity of facial expressions in these kinds of tasks, without finding behavioural differences according to the type of emotion (Denefrio et al., 2017).

Nevertheless, no studies have thus far been conducted using this paradigm on the role of surprise as an orientation cue in the detection of emotional facial expressions. In this study proposal, the orientation cue (facial expression of surprise vs. a neutral one), could appear in the same position (valid trial) or in the opposite one (invalid trial), regarding the target stimulus (facial expressions of happiness, fear, anger, and neutral). This might prompt a situation of surprise (Cue-Surprise) with a degree of uncertainty (50% valid trials), with the aim of studying the process of attentional capture and release regarding the type of facial expression used as target stimuli, thereby simulating a natural situation in which an effective response (swift and without errors) would be adaptive. In this case, the loss is expected of the priming effect of the expression of surprise over the detection of the expression of fear reported in studies by Gordillo et al. (2018, 2019), inasmuch as the expression of surprise would be processed as a different stimulus to the one of fear (it does not appear prior or consecutively to the target stimulus, but instead as an orientation cue, 200 ms before), with its orientation function prevailing. Surprise could be increasing the levels of activation prior to the detection process, with this increase, as certain scholars report, enough to yet further prioritise the selection of threatening stimuli (Lee et al., 2014; Mather and Sutherland, 2011). In this case, the expression of anger regarding all the others, because it would in itself be a direct and threatening stimulus (the person with a facial expression of anger is the actual threat). The use of surprise as orientation cue would be consistent with the approaches that point to a certain overlap between the emotion of surprise and the orientation response (Davidson et al., 2000; Öhman and Wiens, 2003).

The research aim here will therefore be to analyse the effect of the expression of surprise as orientation cue in a Posner task, where the target expressions are ones of fear, anger, happiness, and neutral. The following hypothesis is formulated: *the expression of surprise as orientation cue will facilitate the detection of the expression of anger (shorter RTs and a lower PE) more than those of fear, happiness, and neutral.*

Method

Participants

The research involved a sample of 70 students studying for a degree in Psychology at the Camilo José Cela University (Madrid, Spain), aged between 18 and 29 (M = 21.30, SD = 2.80), with 70% females. All the participants signed an informed consent form before carrying out the task.

Instruments

The task was prepared using E-prime 2.0 software (Schneider et al., 2002), involving 40 standard expressions of surprise, fear, anger, happiness and neutral, captured from eight models (four females and four males; 06F, 08F, 09F, 19F, 21M, 22M, 28M, 29M), taken from the *NimStim Face Stimulus Set* database (Tottenham et al., 2009).

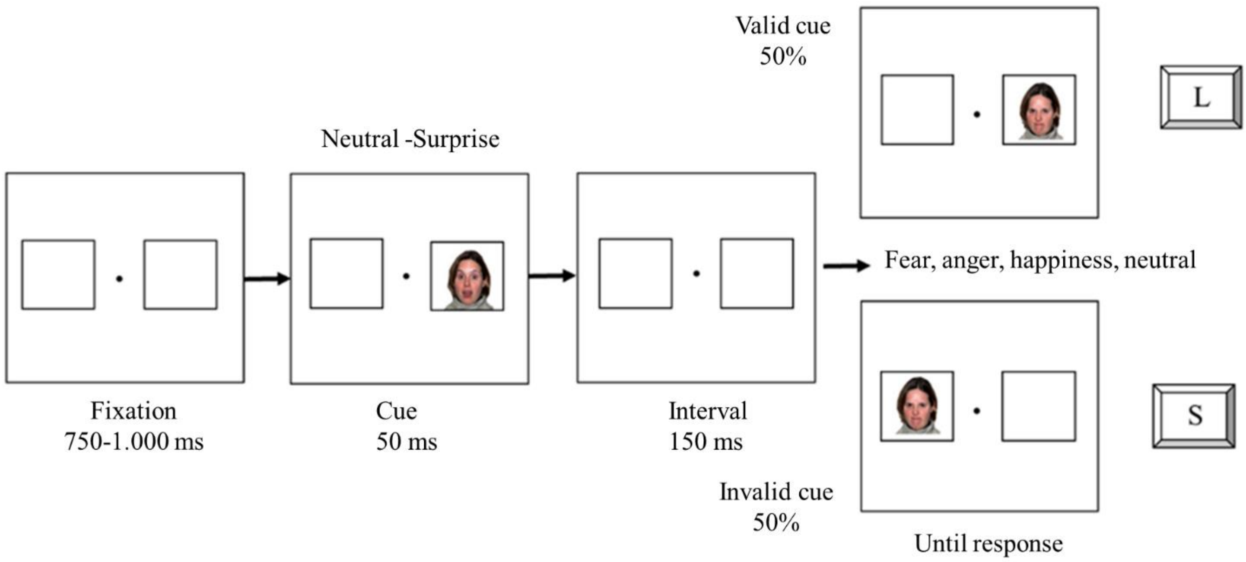
Procedure

The participants were placed in front of a 15” screen with a resolution of 96 x 96 ppp at a distance of approximately 50 cm. They undertook the Posner spatial cueing task on an individual basis, taking an average time of 15 minutes to do so. The computer screen displayed the task's instructions. Before starting, the participants performed 30 practice or trial tests. Upon completion, they were thanked for taking part.

Task

The task began with the display of a point in the middle of the screen with an empty box on each side, appearing for a time that ranged between 750 and 1000 ms. This was followed by the orientation cue, which could be a facial expression of surprise or a neutral one, in the box on the right or on the left, which remained on screen for 50 ms. The next step displayed a screen with two empty boxes for 150 ms. Finally, the target stimulus appeared (facial expression of fear, happiness, sadness, or neutral), which could occupy the same position as the orientation cue (valid cue) or the opposite one (invalid cue). The final screen continued to be displayed until the subjects responded by pressing the "S" key as quickly as possible when the face appeared on the left-hand side, and the "L" key when it did so on the right-hand side, regardless of the type of facial expression. The task consisted of 256 tests, in which each Cue-Target was displayed 32 times, with a 150 ms gap between stimuli, and a stimulus-onset asynchrony (SOA) time of 200 ms. The orientation cues used were peripheral and non-predictive (50% valid - 50% invalid), with the aim being to measure the effects of the exogenous or involuntary attentional orientation prompted by the nature of the stimuli (see Figure 1).

Figure 1
Example of the task, with valid and invalid Cue-Position for a Cue-Content of surprise and a Target Stimulus of anger.



Data analysis

A repeated measures ANOVA was performed, with three independent variables (Cue-Position, Cue-Content, and Target Stimulus). The analyses focused on the results obtained for RTs and PE: 2 (Cue-Position: valid, invalid) x 2 (Cue-Content: neutral facial expression or one of surprise) x 4 (Target Stimulus: facial expressions of fear, anger, happiness, and neutral).

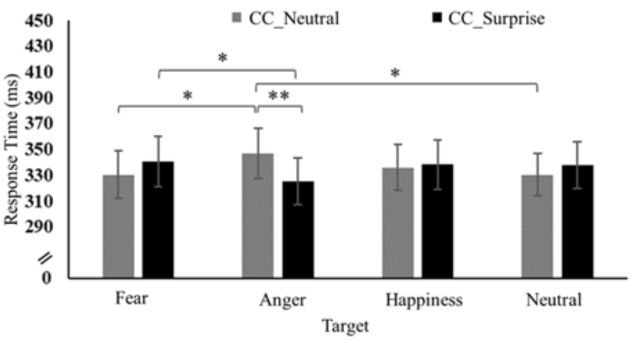
Results

Response times

The Cue-Position factor recorded a significant effect ($F_{(1,69)}$ = 63.17, p < .0001, η_P^2 = .48, P = 1.00; $M_{\text{Valid cue}}$ = 305.15, SE = 16.84; $M_{\text{Invalid cue}}$ = 365.86, SE = 19.52), but not so Cue-Content ($F_{(1,69)}$ = 0.01, p = .938, η_P^2 = 0.00, P = .05), or Target Stimulus ($F_{(3, 207)}$ = 0.17, p = .915, η_P^2 = 0.00, P = .08). No significant effects were recorded either for the interaction between Cue-Position and Target Stimulus ($F_{(3, 207)}$ = 0.81, p = .489, η_P^2 = 0.01, P = .22). There were, however, significant effects for the interaction between Cue-Position and Cue-Content ($F_{(1, 69)}$ = 5.14, p = .026, η_P^2 = 0.07, P = .61), as well as between Cue-Content and Target Stimulus ($F_{(3, 207)}$ = 4.12, p = .007, η_P^2 = 0.06, P = 0.85), and between Cue-Position, Cue-Content, and Target Stimulus ($F_{(3, 207)}$ = 5.12, p = .002, η_P^2 = 0.07, P = .92).

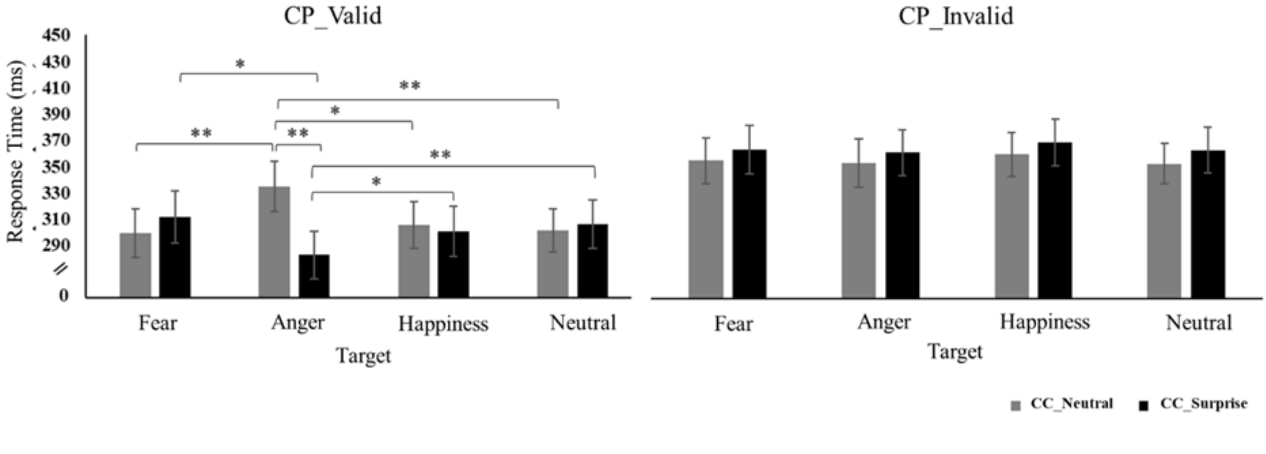
As regards the interaction between Cue-Position and Cue-Content, the Bonferroni analysis revealed that when the Cue-Position was valid, RTs were shorter with a neutral Cue-Content (vs. surprise) ($M_{(i-j)}$ = -10.05, SE = 4.79, p = .040, 95% CI [0.49, 19.61]). In turn, the interaction between Cue-Content and Target Stimulus recorded shorter RTs in the detection of the expression of anger when the Cue-Content was an expression of surprise (vs. neutral) ($M_{(i–j)}$ = -21.73, SE = 6.86, p = .002, 95% CI [8.05, 35.40]). Furthermore, when the Cue-Content was a neutral expression, the expression of anger took longer to detect than that of fear ($M_{(i–j)}$ = 16.74, SE = 7.30, p = .025, 95% CI [2.18, 31.31]) and the neutral one ($M_{(i–j)}$ = 16.76, SE = 6.95, p = .019, 95% CI [2.90, 30.61]). By contrast, when the Cue-Content was an expression of surprise, the expression of anger was detected faster than that of fear (M(i–j) = -15.51, SE = 7.35, p = .038, 95% CI [-30.17, -0.86]) (see Figure 2).

Figure 2
*Differences between the levels of Cue-Content (CC: neutral, surprise) in relation to the type of Target Stimulus (fear, anger, happiness, and neutral). *p < .05, **p < .01.*



As regards the interaction between Cue-Position, Cue-Content, and Target Stimulus, the Bonferroni analysis revealed that when the Cue-Position was valid and the Target Stimulus was an expression of anger, RTs were shorter with a Cue-Content of surprise (vs. neutral) ($M_{(i–j)}$ = -52.17, SE = 8.41, p < .0001, 95% CI [-35.40, 68.94]). Moreover, when the Cue-Position was valid and the Cue-Content was a neutral facial expression, longer RTs were recorded in the detection of the expression of anger compared to the expressions of fear ($M_{(i–j)}$ = 35.48, SE = 8.41, p < .0001, 95% CI [18.71, 52.26]), happiness ($M_{(i–j)}$ = 29.33, SE = 8.43, p = .001, 95% CI [12.51, 46.15]), and neutral ones ($M_{(i–j)}$ = 33.29, SE = 9.01, p < .0001, 95% CI [15.32, 51.25]). Likewise, when the Cue-Position was valid and the Cue-Content was an expression of surprise, the expression of anger was detected faster than those of fear ($M_{(i–j)}$ = -29.00, SE = 9.90, p = .005, 95% CI [-48.74, -9.26]), happiness ($M_{(i–j)}$ = -17.93, SE = 6.43, p = .007, 95% CI [-30.75, -5.10]), and neutral ones ($M_{(i–j)}$ = -23.46, SE = 6.13, p < .0001, 95% CI [-35.68, -11.23]). Finally, the differences between the levels of Cue-Position (valid, invalid) were significant in the cross tabulation of all levels of the variables Cue-Content and Target Stimulus ($M_{(i–j)}$ > -58.11, SE > 9.30, p < .0001) (see Figure 3).

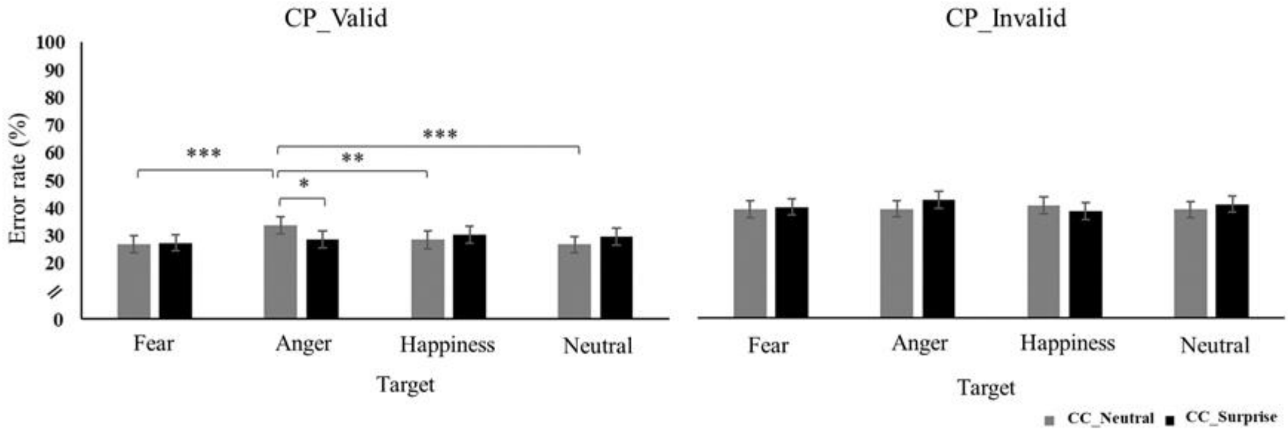
Figure 3
*Differences in RT for the interaction between the factors Cue-Content (CC: neutral, surprise), Cue Position (CP: valid, invalid), and Target Stimulus (fear, anger, happiness, and neutral). *p < .01., **p < .0001.*



Percentage of errors

The Cue-Position factor had a significant effect ($F_{(1,69)}$ = 26.50, p < .0001, η_p^2 = .28, P = 1.00; $M_{\text{Valid cue}}$ = 29.09, SE = 2.89; $M_{\text{Invalid cue}}$ = 41.27, SE = 2.22), as did the Target Stimulus ($F_{(3, 207)}$ = 3.13, p = .027, η_p^2 = 0.04, P = .72), but not that of Cue-Content ($F_{(1,69)}$ = .65, p = .424, η_p^2 = 0.01, P = .13). No significant effects were recorded either for the interaction between Cue-Position and Cue-Content ($F_{(1, 69)}$ = 0.57, p = .452, η_p^2 = 0.01, P = .12); between Cue-Position and Target Stimulus ($F_{(3, 207)}$ = 1.12, p = .341, η_p^2 = 0.02, P = .30); or between Cue-Content and Target Stimulus ($F_{(3, 207)}$ = 1.27, p = .285, η_p^2 = 0.02, P = .34). Nevertheless, significant effects were recorded for the interaction between Cue-Position, Cue-Content, and Target Stimulus ($F_{(3, 207)}$ = 3.89, p = .010, η_p^2 = 0.05, P = .82). The Bonferroni analysis revealed differences between the levels of the variable Target Stimulus, with a lower PE in the expression of anger compared to that of fear ($M_{(i–j)}$ = -2,77, SE = 0.93, p = .024, 95% CI [-5.30, -0.24]). In turn, the third-order interaction recorded a lower PE in the detection of the expression of anger with valid tests when the Cue-Content was an expression of surprise (vs. neutral) ($M_{(i–j)}$ = -5.18, *SE* = 1.90, p = .008, 95% CI [1.40, 8.96]). Furthermore, when the Cue-Position was valid and the Cue-Content was neutral, there was a higher PE in the detection of the expression of anger compared to the expressions of fear ($M_{(i–j)}$ = 6.96, *SE* = 1.73, p < .0001, 95% CI [3.52, 10.41]), happiness ($M_{(i–j)}$ = 5.36, *SE* = 1.69, p = .002, [1.99, 8.73]), and neutral ($M_{(i–j)}$ = 7.05, *SE* = 1.65, p < .0001, 95% CI [3.77, 10.34]) (see Figure 4).

Figure 4
*Differences in Error rate for the interaction between the factors Cue-Content (CC: neutral, surprise), Cue Position (CP: valid, invalid) and Target Stimulus (fear, anger, happiness, and neutral). *p < .05, **p < .01., ***p < .0001.*



Discussion and conclusions

The aim of this research was to study the effect of surprise as an orientation cue in a spatial cueing task involving the detection of facial expressions of fear, anger, happiness and neutral. The results ratify the hypothesis in the condition of valid trials, where surprise as the orientation cue (vs. neutral), benefits solely the Target Stimulus of anger (shortening RTs and reducing PE (Figures 3 and 4). These data are consistent with those recorded in studies that have used different paradigms in which the facial expression of anger is more readily detected than other kinds of facial expressions (Hansen and Hansen, 1988; Horstmann and Bauland, 2006; Calvo et al., 2006; Fox et al., 2000; Mogg and Bradley, 1999; Öhman et al., 2001). Nonetheless, the results contrast with those reported by Gordillo et al. (2018, 2019), where surprise benefits the detection of the expression of fear over anger and happiness when it is presented just before the facial expressions used as Target Stimulus. These results are explained by the priming effect, although in this study the expression of surprise plays the part of orientation cue, partly losing the priming effect on the expression of fear, and more readily priming the detection of the expression of anger.

These results can be explained by the pre-activation effect of the expression of surprise, which has prioritised the detection of stimuli that pose a direct threat, such as expressions of anger, over positive ones (expression of happiness), neutral ones, or threatening signs in the environment (expression of fear). In turn, the results show that the neutral Cue-Content condition is detected less effectively than that of anger (slower RT and higher PE) regarding all the other facial expressions (see Figures 3 and 4), which could indicate a negative effect of the level of activation prompted by the expression of anger when it is not modulated beforehand by the expression of surprise. In other words, the expression of surprise could act as a mechanism for controlling the response, stopping the over-activation prompted in the onlooker by the presence of an expression that requires a rapid response, such as anger, from impairing the response's speed and accuracy. The greater activation of the expression of anger compared to other threatening expressions such as fear could be explained by the differences in its adaptive function. The expression of anger alerts to a social threat that requires avoiding habituation to continue focusing on social signs of anger. Nevertheless, the expression of fear warns of dangers in the environment, whereby becoming habituated to the stimulus would allow focusing on the environment in search of potential dangers (Stoyanova et al., 2007).

These results enable us to delve further into the role of surprise compared to all the other emotions. Recent studies have questioned the existence of six primary emotions, reducing them to four, whereby surprise-fear, and disgust-anger are part of the same emotional dimension (Jack et al., 2014, 2016). Accordingly, when the relationship of continuity between surprise and fear is lost, this will also mean losing the priming effect. In other words, when the expression of surprise is processed as a different stimulus to one of fear, it would act as a warning system for preparing to face a possible threat, and that is when the expression of anger is the stimulus that would more effectively marshal attentional resources, as it constitutes a direct threat.

The studies by Calvo et al. (2006) have shown that threatening expressions require fewer attentional resources for their identification, thereby benefitting from shorter detection times (Efficiency hypothesis). The results obtained here indicate that the expression of surprise, on a prior basis and as orientation cue, could yet further prioritise the detection of the expression of anger over other kinds of threatening expressions such as fear, provided it is processed as an independent stimulus.

Recent studies using facial expressions as orientation cues in spatial cueing tasks have reported that they accelerate the capture process and prolong attentional detachment (Sawada and Sato, 2015). This effect has even been recorded in children, with swifter responses in valid trials with a threatening expression compared to one of happiness (Nakagawa and Sukigara, 2019). Other cases reveal changes in the size of brainwaves that might be reflecting the neurocognitive sensitivity of the emotional content of facial expressions in these kinds of tasks (Denefrio et al., 2017). By including facial expressions as orientation cue and as Target Stimulus, this study has revealed the specific emotional relationship between cue and Target Stimulus, with a high adaptive value within a context of uncertainty (50% valid trials). Also within this context, the expression of surprise primes the expression of anger, reducing RTs and PE in valid trials (favouring attentional attachment). Nevertheless, no effect whatsoever has been found in invalid trials. In sum, it might be posited that responding quickly and without errors is a basic premise for survival, and the expression of surprise would facilitate this process under certain circumstances, revealing a clear distinction between the processing of the threatening facial expressions of anger and fear.

Considering the state-of-the-art on the topic and our findings here, we may conclude that the expression of surprise plays a significant priming role in the detection of facial expressions of anger when they are processed as different stimuli. The study's limitations involve the type of facial expression used. It would be expedient to remove external references to the actual expression (hair, clothing, etc.). Future studies should further explore this process, adjusting SOA times and the display times for the orientation cue in order to analyse the conditions priming the detection of the expression of anger compared to that of fear. It would also be of interest to adjust the levels of uncertainty by changing the percentages of valid trials compared to invalid ones with a view to shedding more light on context's role as modulator in the efficacy of the response, whereby the greater uncertainty, the more pronounced the effect of surprise as an orientation cue will be. Finally, and as noted in certain studies in which the levels of threat are determined by the direction of the gaze (Ewbank et al., 2009; O'Haire, 2011), facial expressions could be considered with differences in the angle of the direction of the gaze as regards the onlooker with a view to analysing its effect in interaction with the type of threatening expression (anger, fear).

Conflict of interest.- The authors of this article declare no conflict of interest.

Financial support.- This work was funded by a research grant awarded by the Camilo José Cela University (8th UCJC Call for research Grants).

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