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Sequential priming in the detection of the facial expression: New approach in the study of emotional detection

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The effective detection of those facial expressions that alert us to a possible threat is adaptive. Hence the reason that studies on face sampling have involved analysing how this process occurs, with evidence to show that the eyes focus mainly on the upper side of the face; nevertheless, no clear determination has been made of the relationship between the efficacy in detection (speed and accuracy) and the way in which emotions are visually tracked on the face. A sequential priming task was therefore held in which the four quadrants of the face were displayed consecutively, for 50 ms each one, and in a different order (24 sequences). The results reveal a quicker response when the priming sequence begins in the upper part, continues downward to the right-hand side of the face, and then follows an anti-clockwise direction. The results are discussed in the light of studies using the Eye-Tracking technique.

The facial expression of emotions plays an important adaptive role, both as a warning signal of the presence of a potential threat, and in the social area, reporting sensitive aspects in communication that could not be conveyed as quickly and effectively in words (see Ekman 2013).

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Sundry studies, therefore, have used eye-tracking techniques to investigate the patterns used mainly in face sampling during social interaction, finding a temporal continuum of visual attention switching between the eyes and the mouth, with differences between people in terms of preferences and the time spent on each one of these positions (Rogers, Speelman, Guidetti, & Longmuir, 2018). These patterns also differ depending on the type of emotion perceived, which would be revealing the degree of specificity in the process of conveying and perceiving important survival information. Specifically, and considering the first three shifting fixations, the eyes remain focused for longer on the lower part of the face when the expressions involve happiness or disgust, and on the upper part in cases of fear and sadness (Schurgin et al., 2014). It has also been verified that these shifting fixations on the face are affected by an initial bias toward the left-hand side, with attention then moving to the right (Everdell, Marsh, Yurick, Munhall, & Paré, 2007).

As regards the expression of fear, the greater focus is on the eye area, which would modulate spatial attention (Carlson & Reinke, 2014), with no differences being found compared to other emotions in the visual attention on the upper and lower parts of the nose, and on the upper part of the lip (Schurgin et al., 2014). Insofar as the expression of fear alerts to a potential threat, its processing will be linked to an attentional bias that will prioritise that information over a neutral expression, as has been found in human beings and primates, which reflects the evolutionary process that has prevailed because of its high adaptive value (Pritsch, Telkemeyer, Mühlenbeck, & Liebal, 2017). In addition, differences have also been found in the face sampling of the expression of fear in different disorders, such as the Turner syndrome (Mazzola et al., 2006), epilepsy (Gómez-Ibañez, Urrestarazu, & Viteri, 2014), autism (Kliemann, Dziobek, Hatri, Baudewig, & Heekeren, 2012), behavioural disorders (Martin-Key, Graf, Adams, & Fairchild, 2017), and dementia (Hutchings et al., 2018). Specifically, a significant deficit has been observed in the facial recognition of negative emotions in certain neurodegenerative disorders, whereby it can be considered an early sign of cognitive impairment (Marcó-García et al., 2019). As a whole, all these data point to the possibility of using face-tracking techniques within the scope of diagnosis (Pavisic et al., 2017; Vargas-Cuentas et al., 2017). Furthermore, these types of techniques are being increasingly used in medical research because they lead to more reliable clinical decisions (Brunyé, Drew, Weaver, & Elmore, 2019).

Although all these studies report on the temporal sequence of visual attention, there is no clear information on the efficacy of the detection according to the way in which people track facial information. In other words, these studies enable us to determine visual attention on the face, but they do not analyse the patterns of that focus (response times and accuracy rate) compared to others. What's more, an analysis based on eye tracking is expensive, thereby restricting its use in diagnostic tests, so a method that permits an accurate analysis of the processing of facial information would facilitate its inclusion in different ambits. This would be the case within a clinical setting, as we have already noted, and also in psychology research, where the goals often focus on identifying the type of emotion that is best detected or recognised, and which cognitive processes could modulate this response (e.g., perception, attention, memory, and decision-making).

This research therefore addresses a task that involves displaying faces, divided into four quadrants, in a sequence of images that have a priming effect on the emotional expression to be detected. This procedure would permit identifying the most effective display sequence in the discrimination of different emotions, in terms of both reaction time (RT-ms) and detection rate (DR-parameter A´).

Concerning the expression of fear, the most effective sequence may well be the one that begins displaying the face's upper quadrants (greater focus on the eye area), as reported in the scientific literature (Everdell et al., 2007; Schurgin et al., 2014). This approach, from the paradigm of sequential priming, is based on the effect the priming stimulus would have on the speed of processing of the target, and where the similarity between prime and target would be crucial. This means the priming sequence that best facilitates the discrimination, in this case the expression of fear, would in turn reflect the best display sequence or the most suitable face-tracking pattern for facilitating the discrimination of these kinds of expressions.

For the purpose of studying the processes involved in the facial expression of emotions, priming studies have used different stimuli as prime and/or target (words, images, sounds, and facial expressions), with the emotional congruence between them being the variable that mostly determines the facilitation effect (Aguado, Martínez-García, Solís-Olce, Dieguez-Risco, & Hinojosa, 2018; Carroll & Young, 2005). In addition, it has been noted that an implicit automatic processing of the prime, using as stimuli the eye area with a different emotional expression, sufficed to generate an emotional congruence effect in a lexical decision task (Wagenbreth, Rieger, Heinze, & Zaehle, 2014). Specifically, regarding the detection of the facial emotion, recent studies on eye tracking have reported that brief displays of emotional facial expressions (prime of 50 ms) led to an early focus of the eyes on the target (neutral expression), which differed depending on the type of prime; in other words, when the expression was one of fear, the subjects focused more quickly on the eye area, whereas when it was of happiness, they focused more quickly on the mouth area

(Bodenschatz, Kersting, & Suslow, 2018). As this study contends, the priming's display time determines the degree of clarity with which the subject processes the information, whereby it is important to tailor it to the research goals so that the priming effect occurs with a low but effective level of awareness when generating that selfsame effect (see Lohse & Overgaard, 2019).

Taking all these data together, it is to be expected that a methodology that briefly and consecutively displays all the possible combinations of the four quadrants of the face (24 sequences) will enable us to study and identify those sequences that will more readily facilitate the detection of the different emotional facial expressions. Specifically, and regarding the facial expression of fear, it is to be expected that those sequences that fully or partially coincide with the visual tracking of an expression of fear during a detection task (as per the studies involving the eye-tracking technique) would be the ones to more readily facilitate the subject's response (priming effect). This methodology would provide similar results to those found using the eye-tracking technique, albeit involving procedures that are less intrusive, more precise, and of greater use for research into basic psychology.

The aim here is therefore to analyse the differences in response time (RT) and detection rate (DR) of all the possible combinations of the four face quadrants, displayed as prime, in detecting the facial expression of fear. That the sequences starting in the upper part of the face are expected to generate the shortest RTs and the highest DR (H_1). These hypotheses would be explained according to the studies that report how specifically when the face expresses fear there is a tendency to hold the shifting fixations on the eyes for longer (Schurgin et al., 2014).

METHOD

Participants. The sample consisted of 114 students (69.3% Women; M ± SD age, 19.67 ± 1.56) from the Faculty of Higher Studies of Zaragoza (Mexico), who took part in exchange for an increase of 0.50 points out of ten in their marks for the subject. A power calculation using G*Power (version 3.1.9.2) (Faul, Erdfelder, Lang, & Buchner, 2007) showed that 91 participants would be sufficient to detect a medium effect size (Cohen´s d = 0.60) at $\alpha = 0.05$, with power of 0.95, in an a priori analysis of repeated measures within factors (third level analysis). All the participants had normal or corrected-to-normal visual acuity and were right-handed. After the procedures had been explained, all the participants gave their informed consent to participate. The ethics committee at the Camilo José Cela

University assessed the study protocol and declared it exempt from a full ethical review.

Materials. The task's programming involved the use of E-prime software, and the stimuli were displayed on a 15" screen, at a distance of approximately 50 cm from the participants. The 20 expressions used were prototypes of fear and neutrality, which were taken from the NimStim Face Stimulus Set (Tottenham et al., 2009). The facial expressions used in the test phase were provided by ten models, five women and five men, and were displayed in the centre of the screen, measuring 4 cm in width and 5 cm in height.

Data availability. The datasets generated and analysed during the current study are available at this link: https://drive.google.com/drive/folders/1QgX1rlTPOPVwe0Edwd_Sm8PJS4FCC43y?usp=sharing.

Procedure. A Prime-Target paradigm was established, where the prime was formed by the four quadrants of the face, which were presented consecutively, with an exposure time of 50 ms each. For example, to establish the prime of condition S_35, first the upper-right quadrant (50 ms) is presented, followed by the lower-right (50 ms), lower-left (50 ms) and upper-left (50 ms). Finally, following the consecutive display of the face's four quadrants (prime), the subject was shown a full expression of fear or a neutral one (target), for 1,000 ms. The subject is instructed to respond as quickly as possible by pressing a key when the expression is one of fear, and not to do so when it is neutral. The prime and target in each trial have the same emotional category; that is, when the target is a neutral expression, it will be preceded by a prime with the quadrants of a neutral expression, and when the target is an expression of fear, it will be preceded by a prime with the quadrants of an expression of fear. The model used in each trial coincides for both prime and target.

The representation of this sequence can be seen in Figure 1 (S_35). This meant all possible combinations were displayed in 24 sequences. The sequences have been grouped into different levels of analysis: level S_1 groups them according to where the first quarter of the face begins (four sequences); level S_2 groups them according to where the first two quarters of the face begin (12 sequences), and level S_3 considers all 24 sequences (see figure 1). In total, 480 trials were presented, half with neutral facial expressions, and the other half with facial expressions of fear. The participants were instructed to press a key as soon as they recognized the target of fear, and not to do so (to be inhibited) when the target was a neutral expression (see Figure 1).

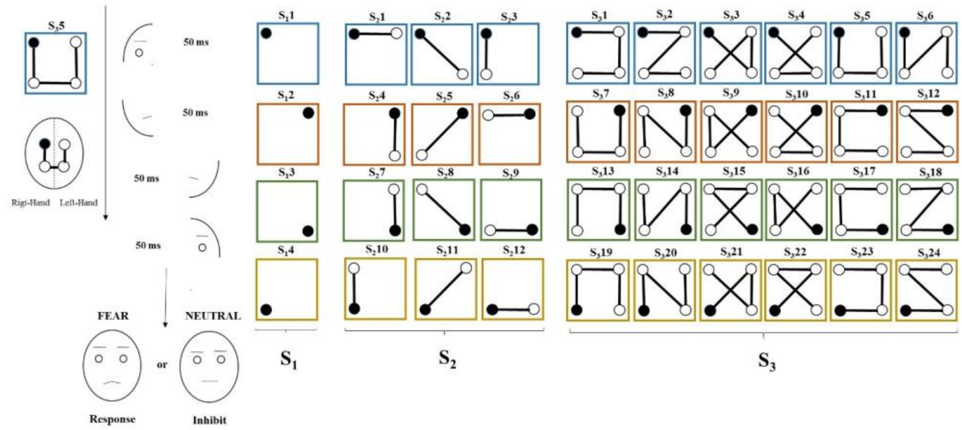

Figure 1. Example of experimental condition S_35, and representation of all the sequences, by levels of analysis: level 1 (S_1), level 2 (S_2) and level 3 (S_3). The right- and left-hand side of the face are seen from the perspective of the face perceived, not from the perspective of the perceiver.

Data analysis. A repeated measures ANOVA has been performed of 2 (Lower, Upper) x 2 (Left-Right), with the independent variables being the position where the sequences begin on the y-axis (Vertical: Lower-Upper), and on the x-axis (Horizontal: Left-Right), for the purpose of verifying Hypothesis on the expected bias in the detection of the expression of fear (shorter RTs and higher A') when the sequences begin in the upper part of the face compared to when they begin in the lower part.

In addition, three unifactorial repeated measures ANOVA were performed with the variable Prime, with three levels of analysis: level 1 with four sequences (Fig. 1, S_1), level 2 with 12 sequences (Fig. 1, S_2), and level 3 with 24 sequences (Fig. 1, S_3). The dependent variables were Reaction Times (RTs accurate trials, ms), and the Detection Rate (DR, A'). Signal detection theory procedures were used to measure the detection rate, starting from parameter A' (Donaldson, 1992). A´ is a nonparametric analogue of d' that obtains values between 0 and 1, with 0.5 being the value assigned to a random discrimination. The following formulae were used (Donaldson, 1992):

H = hits; FA = false alarms:

$A' = 0{,}5 + [(H-FA)(1+H-FA)] / [4H(1-FA)]$, if $H > FA$

$A' = 0{,}5$, if $H = FA$

$A' = 0{,}5 - [(FA-H)(1+FA-H)] / [4FA(1-H)]$, if $H < FA$

RESULTS

The The repeated measures ANOVA provided the main effects on the RTs of the variable Vertical ($F_{(1, 113)} = 30.14$, $p < .0001$, $\eta_p^2 = .21$), with shorter RTs when the sequence began in the upper part of the face (*M* = 480.04, *SD* = 91.59), compared to when it began in the lower part (*M* = 490.53, *SD* = 94.74); nevertheless, no main effects were observed of the variable Horizontal ($F_{(1, 113)} = .06$, $p = .812$, $\eta_p^2 = .00$), or of the interaction between vertical and horizontal ($F_{(1, 113)} = 2.26$, $p = .136$, $\eta_p^2 = .02$). In turn, no main effects were observed on the DR variables of the variables Vertical ($F_{(1, 113)} = 1.56$, $p = .214$, $\eta_p^2 = .01$), Horizontal ($F_{(1, 113)} = .15$, $p = .704$, $\eta_p^2 = .00$), or of the interaction between the variables ($F_{(1, 113)} = .46$, $p = .498$, $\eta_p^2 = .00$).

First level analysis (S_1). The ANOVA revealed the significant main effects of prime on RT ($F_{(3,111)} = 10.62$, $p < .0001$, $\eta_p^2 = .22$). The analysis of the simple effects (Bonferroni) showed differences between sequence $S_1 1$ and sequences $S_1 3$ ($M_{(i\text{-}j)} = -10.91$, $SE = 2.69$, $p = .001$) and $S_1 4$ ($M_{(i\text{-}j)} = -12.91$, $SE = 2.50$, $p < .0001$); and between sequence $S_1 2$ and sequences $S_1 3$ ($M_{(i\text{-}j)} = -8.07$, $SE = 2.50$, $p = .010$) and $S_1 4$ ($M_{(i\text{-}j)} = -10.07$, $SE = 2.52$, $p = .001$). On the other hand, there were no significant effects of the prime on DR ($F_{(3,111)} = .73$, $p = .537$, $\eta_p^2 = .02$) (see Figure 2).

Second level analysis (S_2). The ANOVA revealed significant main effects of prime on RT ($F_{(11,103)} = 5.38$, $p < .0001$, $\eta_p^2 = .37$). The analysis of the simple effects (Bonferroni) evidenced that the differences were between the sequence $S_2 3$ and sequences $S_2 8$ ($M_{(i\text{-}j)} = -15.11$, $SE = 3.89$, $p = .012$), $S_2 9$ ($M_{(i\text{-}j)} = -25.53$, $SE = 4.29$, $p < .0001$), $S_2 10$ ($M_{(i\text{-}j)} = -16.93$, $SE = 4.04$, $p = .004$), $S_2 11$ ($M_{(i\text{-}j)} = -15.87$, $SE = 4.13$, $p = .013$), and $S_2 12$ ($M_{(i\text{-}j)} = -23.33$, $SE = 3.88$, $p < .0001$). Furthermore, there were no significant effects of the prime on DR ($F_{(11, 103)} = .88$, $p = .567$, $\eta_p^2 = .09$) (Figure 2).

Third level analysis (S_3). The ANOVA revealed significant main effects of prime on RT ($F_{(23,91)} = 2.90$, $p < .0001$, $\eta_p^2 = .42$). The analysis of the simple effects (Bonferroni) evidenced that the differences were between $S_3 5$ and the conditions $S_3 15$ ($M_{(i\text{-}j)} = -25.26$, $SE = 6.17$, $p = .022$), $S_3 17$ ($M_{(i\text{-}j)} = -30.38$, $SE = 6.30$, $p = .001$), $S_3 18$ ($M_{(i\text{-}j)} = -31.67$, $SE = 6.14$, $p <. 0001$), $S_3 22$ ($M_{(i\text{-}j)} = -24.04$, $SE = 5.63$, $p = .011$), $S_3 23$ ($M_{(i\text{-}j)} = -28.73$, $SE = 6.04$, $p = .002$), y $S_3 24$ ($M_{(i\text{-}j)} = -28.91$, $SE = 6.07$, $p = .002$). Finally, there were no significant effects of the prime on DR ($F_{(23, 91)} = 1.07$, $p = .391$, $\eta_p^2 = .21$) (see figure 2).

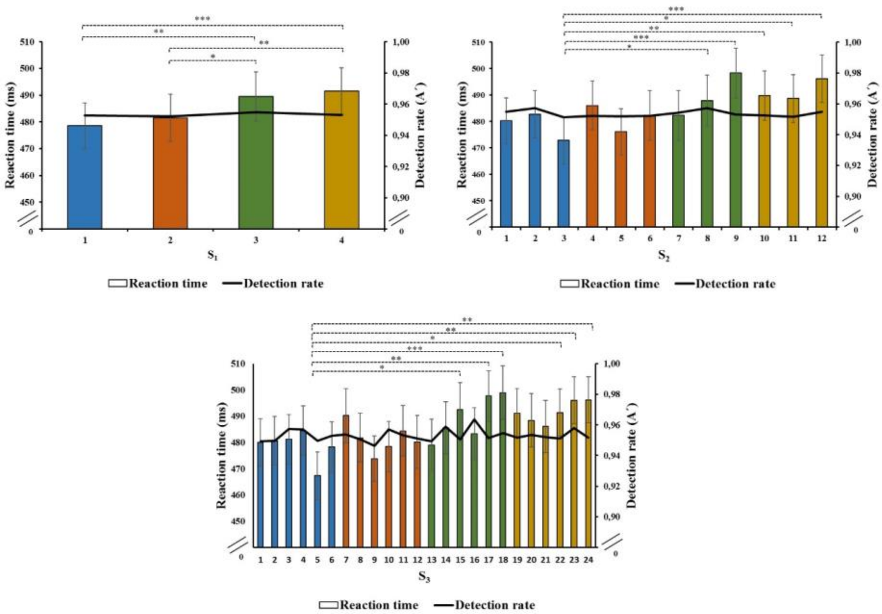

Figure 2. Graphic representation of the differences between sequences (level, 1, 2 and 3) for the dependent variables Reaction Time (RT) and Detection Rate (DR). Error bars are standard errors of the mean. *p < .05, **p < .01, ***p < .0001.

DISCUSSION

The aim of this research was to analyse the sequences of the detection of the facial expression of fear through a priming procedure. The results obtained show there is a quicker response when the priming sequence starts in the upper part of the face ($S_1$1 and $S_1$2), continues downward on the right ($S_2$3), and follows an anti-clockwise direction ($S_3$5), with no differences being found in the DR (A´). These data are consistent with prior research using the eye-tracking technique (Everdell et al., 2007; Schurgin et al., 2014), revealing very specific tracking patterns in the first shifting fixations. These studies, however, record the tracking patterns but do not provide any data on the efficacy (speed and accuracy) of a specific one compared to the others.

These data could be explained by the shorter RTs involved in moving from the upper right quadrant to the lower right one ($S_2$3), regarding the other quadrants. This shorter time has been verified in paradigms such as visual tracking (Carroll & Young, 2005), where the valid trials that involve detecting a target following its appearance in the same position as a prior signal mean a shorter RT than invalid trials, where the subject needs to change the visual attention from the right-hand side to the left or vice versa.

Furthermore, when the cues are emotional expressions, there is a reduction in valid trials and an increase in invalid ones (Sawada & Sato, 2015); in other words, RTs increase in paradigms of this nature, when the subjects are "forced" to change their focus from left to right or vice versa, and the focus cue is a face. Nevertheless, the same effect is not found in those sequences that display the first two quadrants of the face on the same side ($S_2$4, $S_2$7, $S_2$10, see figure 1). This suggests that the facilitating effect of the $S_2$3 sequence is informed not only by the advantage of displaying the face's first two quadrants on the same side, but also by the fact that the first display involves the upper right-hand side of the face ($S_3$5, see figure 1), thereby facilitating the expression of fear over other kinds of expression such as happiness or disgust, where the visual attention is focused more on the lower area, as confirmed by eye-tracking techniques (Everdell et al., 2007; Schurgin et al., 2014). Nevertheless, no significant differences have been found in the detection task, which may be due to its relative ease (pressing a key when an expression of fear is displayed) and the ample amount of time the target is displayed (1,000 ms), which might have prompted a ceiling effect. It should also be considered, nonetheless, that an adaptive response to potential dangers in people's everyday lives does not stem so much from an error in the response (not perceiving the threat) but instead from a delayed reaction.

The procedure used in this research leads to a better understanding of the patterns of face sampling, based on an analysis of the automatic response to the incoming information (sequential priming), and at a low cost compared to eye-tracking techniques, where the subject's shifting fixations are recorded when emotional expressions are displayed for the purpose of locating the most sensitive regions. The sequential priming procedure permits handling the incoming information to identify the sequence that best fits the target stimulus, in this case the facial expression of fear, generating the shortest RTs, and therefore facilitating the discrimination of that emotion. In short, the sequence that generates the shortest RTs would determine the most suitable location for the visual attention, for reacting quickly without losing any accuracy in the response to a facial expression of fear. This research has found that this sequence would be as follows: Upper right / Lower right / Lower left / Upper left ($S_3$5).

Furthermore, consideration should also be given to the type of task to which this methodology is applied. The priming sequences that more readily facilitate the response are expected to be different in the case of a recognition task as opposed to a detection one, insofar as they involve different mechanisms (Sweeny, Grabowecky & Paller, 2018); in addition, the pairs of stimuli displayed also determine the type of sequence the subject will prioritise; in other words, the sequences that more readily facilitate the recognition of the expression of fear compared to the neutral one will be different to those that facilitate the recognition of the expression of fear compared to the expressions of anger, happiness or sadness. There is no doubt that the type of task (recognition vs. detection) and the comparison pairs are variables that will need to be considered in future research, bearing in mind that detection and recognition involve partially separate mechanisms, and what's more, that the expression of fear is more readily detected than recognised (Smith & Rossit, 2018).

The processing of facial information in different disorders does not occur in the same way as among the general population. In the case of autism, these difficulties have been linked to the tendency to avoid eye contact (Hadjikhani et al., 2017; Tanaka & Sung, 2017), which would also be associated with an abnormally high activation in subcortical regions, such as the superior colliculus, the pulvinar nuclei of the thalamus, and the amygdala, as regions involved in visual attention processes (Tsang, 2018). In both cases, this would compromise the proper processing of facial information. This paradigm would therefore have implications in the clinical field, as a low-cost diagnostic test in different disorders that involve a deficit in emotional detection, such as autism, where a greater awareness would be expected in the response to sequences that begin in the upper area, with an inverse response pattern to the one expected among the general population. It could likewise be used in schooling for the early detection of problems in recognising facial emotions, which might interfere with academic performance (Roos et al., 2014).

Finally, these studies should be extended to all the other facial expressions of emotions, with a view to drawing up an "alphabet" of the characteristic priming sequences of the different facial expressions that would have a clear parallelism with Ekman's approach to facial coding based on muscular movements (Ekman & Friesen, 1971), although in this case informed by priming sequences that could be easily embedded in software for the purpose of reducing RTs and increasing the efficacy of the discrimination of the information conveyed by facial expressions, either within the field of security or in the training of the security forces (Damjanovic, Pinkham, Clarke, & Phillips, 2013). Accordingly, exposure times and stimulus onset asynchrony (SOA) would have a significant role to play in the modulation of the expected effects, which should also be taken into account in future studies in order to conduct a more in-depth analysis of aspects such as the automatic vs. controlled component. Finally, it would also be of interest to analyse the consistency and inconsistency between the expressions used as prime and target, as well as the variables gender and age. Although no clear gender differences in emotional perception have been reported in the scientific literature, the type of methodology used may explain these inconsistencies (Fisher, Kret, & Broekens, 2018), whereby the method proposed here might provide clarity on this point. Finally, the model has the following limitations: 1) It has little ecological validity, insofar as the aspects involved in emotional processing do not tend to appear in a static manner within people's natural sphere of action; 2) A comparative analysis is required of the results considering other emotional categories, with the aim being to verify whether previous findings arise from the nature of the task itself, regardless of the type of emotion analysed or, by contrast, they are informed by the task's sensitivity toward the type of expression (happiness, sadness, fear, anger, disgust), the type of processing (detection *vs.* recognition), and the display intervals between the parts of the face used as prime; 3) The sample (university students with a higher percentage of women) is not conducive to the extrapolation of the results. Future research should address all these points with a view to providing a model that is sensitive to changes in the processes for detecting the facial expression of emotions.

RESUMEN

La eficacia en la detección de las expresiones faciales que nos alertan de una posible amenaza es adaptativa. Por esta razón, los estudios sobre rastreo facial se han interesado en el análisis de este proceso, encontrándose evidencias de que la mirada se enfoca prioritariamente a la parte superior del rostro; sin embargo, no se ha establecido de manera clara la relación entre la eficacia en la detección (velocidad y precisión) y la forma en la que se rastrean las expresiones faciales emocionales. Con el objetivo de aportar claridad en este punto, se realizó una tarea de priming secuencial en la que se mostraban los cuatro cuadrantes de la cara de manera consecutiva, durante 50 ms cada uno, y en un orden diferente (24 secuencias). Los resultados mostraron una respuesta más rápida cuando las secuencias de priming comenzaban en la parte superior, continuaban hacia abajo en el lado derecho, y posteriormente seguían la dirección contraria a la agujas del reloj. Se discuten los resultados a la luz de los estudios que utilizan la técnica de Eye-Tracking.

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