Psicológica (2016), 37, 127-150.

Where to look when looking at faces: visual scanning is determined by gender, expression and tasks demands

Elisa Pérez-Moreno*, Verónica Romero-Ferreiro & Ana García-Gutiérrez

Universidad Complutense de Madrid, Spain

Visual scanning of faces was studied during categorization of expression and gender with the aim of revealing possible differences in the perceptual mechanisms that mediate analysis of these facial properties. A more distributed scanning pattern, with increased fixation in the lower face, was observed in the expression compared to the gender task. Distribution of fixations across the upper and lower face also varied depending on the specific gender and expression of the viewed faces, with female faces and faces showing anger attracting more fixations to the eye region. Variations reflecting an interaction between gender and expression were also observed. However, the nature of these modulations suggests a differential influence of perceptual interactions and social/affective value on eye movement measures and on pupil size. Collectively, these results show that the visual inspection of faces is determined in a complex manner by the specific demands of different categorization tasks and by the perceptual and social/affective properties of the emotional expressions shown by either male or female faces.

Eye movements have been studied extensively to explore the way in which visual inspection behavior guides scene and object perception (e.g., Duchowski, 2002; Hoffman, 1998; van Gompel, Fischer, Murray, & Hill (2007). Different fixation measures such as location, duration or the sequence of fixation shifts reveal that seeing is an active process whereby relevant information is gathered from any *area of interest* (AOI) in the

---

* Correspondence concerning this article should be addressed to Elisa Pérez-Moreno, Facultad de Psicología, Universidad Complutense, Campus de Somosaguas, 28223, Madrid, Spain. E-mail: elisaperez@psi.ucm.es. This work was supported by grant Psi2010-18682 from the Spanish Ministerio de Ciencia e Innovación. Participation of Verónica Romero was possible thanks to a pre-doctoral fellowship from the Universidad Complutense de Madrid. We must thank Dr. Luis Aguado for his valuable comments to improve the final manuscript.

visual field, areas which contain richer information for the perceiver´s current goals (e.g., Henderson, 2003; Rayner, 2009). In the context of face perception, eye movement research provides crucial evidence for the hypothesis that visual inspection of faces tends to optimize information gathering for different tasks involving judgments of socially relevant properties such as the identity, gender, gaze direction or expression of faces (Bruce & Young, 1986). This hypothesis is based on the evidence that not all face regions are equally informative and different diagnostic information is needed for different categorization tasks. For example, it has been possible to derive the specific facial features used for different face recognition tasks through techniques that allow precise control over the face region visible to the observer such as "Bubbles" (Gosselin & Schyns, 2001) or "Spotlight" (Caldara, Zhou, & Miellet, 2010). The results obtained with these techniques confirm the intuition that the eye region is critical for many face related judgments. Furthermore, differences have been found between tasks in the relative diagnostic value of information from the upper (eye region) and lower (nose and mouth) face regions. According to these results, while the eye region is critical for gender and expression categorization, discriminating between expressive and non-expressive faces seem to rely more on information from the mouth region (Gosselin & Schyns, 2001; Schyns, Bonnar, & Gosselin, 2002; Smith, Cottrell, Gosselin, & Schyns, 2005). This is not surprising given that facial expressions of emotion usually involve displacement of facial features in the eye and the mouth regions (e.g., Ekman & Friesen, 1978) and that identification of facial expressions is heavily dependent on configural processing of the whole face (e.g., Calder, Young, Keane, & Dean, 2000).

Information on how diagnostic value of different regions of the face guide visual behavior can be gained by comparing the pattern of eye movements under different task conditions. However, only a few studies have compared visual scanning across different categorization tasks. Single task studies have indeed confirmed the preferential use of information from the eye region in face recognition (e.g., Barton, Radcliffe, Cherkasova, Edelman, & Intreiligator, 2006; Caldara et al., 2010; Henderson, Williams, & Falk, 2005; Mäntylä & Holm, 2006) and in expression categorization (Hall, Hutton, & Morgan, 2010; Vassallo, Cooper & Douglas, 2009). In one of the studies that have included across-task comparisons (Malcolm, Lanyon, Fugard, & Barton, 2008), participants judged which of two probe faces was similar to a previous target face in terms of identity or expression. More scanning of the upper face corresponded to identity matching and more scanning of the lower face to expression matching. The most thorough comparison between tasks conditions is suggested in Peterson and Eckstein

(2012). In this study, identity, gender and expression tasks were compared under restricted and free-viewing conditions that allowed only a single saccade into the face stimuli (350 ms allowed to perform the first saccade from different start positions). The average end position of these first saccades was located not on the eyes themselves but in a region just below the eyes. Moreover, moderate differences were found in the optimal fixation regions across tasks. Saccades closer to the eyes were observed in the gender task and a downward shift in saccadic movements was observed in the emotion task. These results were interpreted as revealing a strategy of eye movements where saccades are directed to a region that allows maximal integration of information across the entire face. Consequently authors proposed the hypothesis that directing the high-resolution fovea toward the eye region has functional importance for the sensory processing of the face. Moreover, this behavior optimizes basic perceptual tasks considered relevant to survival, such as tasks involving discrimination of identity, expression, and gender of the face. However, this pattern of movements is task-specific (Buchan, Paré, & Munhall 2007). Task-dependent variations of this strategy, such as the downward shift in expression tasks, would be related to variation in the concentration of relevant information for different tasks across face regions. It is interesting in this sense that when participants were assigned the task of discriminating between happy and neutral faces a significant downward shift from the identification condition was observed, reflecting the fact that the most discriminative information for this task is concentrated in the mouth region. The evidence discussed above converges in showing that the eyes and surrounding face region are the main targets of visual inspection in several face categorization tasks. However, this evidence also suggests that visual scanning is modulated by the particular demands of the specific task at hand. In the expression discrimination task, this modulation is consistent with the high diagnostic value that has the information from the lower face, specially the mouth area.

Considering the importance that specific-task demands could have on the visual scanpaths, the main aim of this study was to explore further the patterns of visual scanning in a categorization task including gender and expression by directly comparing eye movements. In order to increase the probability of finding differences between tasks, faces were presented for a relatively long duration (1 sec), because more extended scanning allowed for more than one fixation.

The second goal of the experiment was to study possible within-task variations and the effects of the interaction between different facial properties. In the case of expression discrimination, one factor that might modulate visual scanning is the relative weight of the upper and lower face in different expressions. Although full emotional expressions involve simultaneous changes in the eye and mouth regions, there are clear differences in their relative dominance for the recognition of different expressions (Bassili, 1979; Calder et al., 2000; Ekman, Friesen, & Ellsworth, 1972). For example, while smiling faces are more easily recognized from the bottom half of the face, angry faces are more recognizable from the top half (Calder et al., 2000; Lundqvist, Esteves, & Öhman, 1999; Matsumoto, 1989). Accordingly, differential scanning of the upper and lower face should be expected for these two expressions. In fact, there is evidence pointing that the eye region used to be preferentially fixated during visual scanning of threatening faces (Green, Williams, & Davidson, 2003a, b).

As for the interaction between facial properties, there is behavioral evidence that classification of the expression and gender of faces are not completely independent tasks. Further, the classification of one of these dimensions cannot be performed without being influenced by the other, apparently irrelevant dimension. Interference (higher RT times) of expression on gender classification but not the opposite (that is, interference of gender on expression) was shown by Atkinson, Tipples, Burt and Young (2005), using the Garner paradigm that involves orthogonal variation of expression and gender. However, symmetrical interaction of gender and expression was obtained in a study by Aguado, García-Gutiérrez and Serrano-Pedraza (2009). In this case, expression categorization was influenced by the gender of the face, and gender categorization was also influenced by expression. For example, male angry faces were classified faster in terms of both gender and expression. Biases in gender classification induced by emotional expression have also been shown in several studies (Hess, Adams, & Kleck, 2005; Hess, Adams, Grammer, & Kleck, 2009; for a theoretical review see Hess, Adams, & Kleck, 2009). Complementarily, other studies have further documented the influence of expression on gender classification (Hugenberg & Sczesny, 2006; Kawamura, Komori & Miyamoto, 2008). Concretely, in our laboratory, we have found that in a dual task design, similar to the one used in the current study, gender categorization was significantly impaired by the concurrent demand to categorize expression, while performance of expression task kept constant (García-Gutiérrez, Aguado, Romero-Ferreiro & Pérez-Moreno, 2015).

A common interpretation of the interaction between gender and expression in face perception is that it is based on the overlap of features with high diagnostic value for both tasks (e.g., Hess, Adams, & Kleck, 2009). Face image analysis supports this view. For example, in Kawamura et al., (2008), a *Principal Component Analysis* (PCA) of the face images revealed a component that explained a high proportion of variance for both the facial expression and the gender of the face. In the specific case of angry and happy expressions frequently used in studies on gender and expression interaction, there is evidence that markers for these two emotions overlap with those relevant for evaluative judgments such as dominance/affiliation or trustworthiness (Oosterhof & Todorov, 2008) and also in gender discrimination (Becker, Kenrick, Neuberg, Blackwell, & Smith, 2007; Hess, Adams Jr, & Kleck, 2007, 2009; Kawamura et al., 2008). For example, it is known that reducing the brow-to-lid distance makes a face look at the same time more masculine and angry (e.g., Becker, et al., 2007; Burton, Bruce, & Dench, 1993). According to this, it has been shown that expressive markers such as raised or lowered eyebrows that are characteristic of fear and anger faces respectively, tend to overlap with the facial features that provide an appropriate cue for gender classification. Accordingly, Hess, Adams, Grammer, and Kleck, (2009), found happiness and fear expressions biased sex discrimination toward the female, whereas angry expressions biased sex perception toward the male.

In the present study, participants were asked to classify the gender or the expression in two different blocks. Accuracy response and different ocular variables were measured during stimulus presentation. Based on the evidence discussed above and assuming that visual inspection of faces tends to optimize information gathering for different tasks, we predicted that visual scanning of faces should be determined by the nature of the task (expression or gender classification) and also by the specific combination of face gender and expression (for example, angry females or angry males).

For the analysis of eye movements, two facial AOI were defined previously: The upper face (eye area) and the lower face (mouth area). The main ocular variables were the number and duration of ocular fixations. This choice was based on the fact that visual information is acquired during fixation, when visual processing can be performed with high acuity by the fovea and no visual information is acquired during saccades (Leigh & Zee, 1999). Moreover, the distribution of fixations across the upper and lower face provides crucial information about what facial features are attended preferentially under different stimulus and task conditions. Saccadic amplitude was also considered. This measure was defined as the distance between two fixations. Therefore, this measure is interesting because it provides useful information about how detailed or concentrated the visual scanning of the face is. Finally, we also measured pupil size. Changes of this psychophysiological measure are thought to reflect cognitive load (Hyönä, 1995; Kahneman & Beatty, 1966) and are also associated to emotional arousal (Bradley, Miccoli, Escrig, & Lang, 2008). Moreover, it has been recently shown that perception of some facial expressions produces pupil responses in the observer (Tamietto et al., 2009). Although secondary to the aims of our study, this measure might provide valuable evidence on the cognitive and emotional mechanisms underlying perception of facial expressions of emotion under the specific conditions of this study. Finally, a specific analysis was carried out for the first fixation, concretely: entry time, position and duration of the first fixation at the stimuli. The entry time reflects early attentional processes. It was defined as the time lapsing between stimulus onset and the first fixation on the AOI in milliseconds (Jacob & Karn, 2003). It represents a measure for initial orienting or for higher efficiency in locating a specific AOI (Holmqvist et al., 2011).

METHOD

Participants. Participants were 24 psychology students (20 females and 4 males) from the Complutense University (Madrid, Spain), who participated in the experiment for course credits (M_{age} = 19.29, SD = 1.63). All of them with normal or corrected-to-normal vision, assessed by self-report.

Apparatus and Stimuli. Ocular dependent variables were monitored with a remote eye-tracking system (ASL Model 5000). The system, with accuracy of 0.5°-1° visual angle, provided eye-gaze coordinates and pupil size with a sampling rate of 60 Hz. Participants were seated at a distance of 205 cm from the screen (142 cm x 106 cm) where targets appeared. Head position was controlled with a head and chin rest. The screen subtended 38° of visual angle horizontally and 29° vertically. The ocular camera system was placed at a distance of 84 cm from the participant´s eye, avoiding any interference with gaze. Manual responses were registered through a keyboard with keys covered except those required to respond. Synchronization between the eye tracking system and the running program produced a video scene, visible only to the experimenter, with a pointer showing the position where the participant was looking at. Sessions were carried out individually in a soundproof, dimly lit room. In order to control the significance of pupil data, the luminance taken from the eye was kept at a constant level of 4 lux. The measurement of luminance was carried out with the Digital Lux Meter ISO-TECH - 1332A.Targets were 32 pictures corresponding to 16 models (8 male, 8 female) showing either happy or angry expression, taken from the KDEF collection (Lundqvist & Litton, 1998). Images were cut to conceal most of the hair. Moreover, in order to avoid the fact that saliency of the white teeth hold the attention due to the opening of the mouth in happy and angry faces, this area was blurred using a 10 pixel Gaussian filter (see Aguado, Serrano-Pedraza & García-Gutiérrez, 2014). Moreover, images were equated in contrast energy (root mean square contrast or cRMS = 0.2, see Aguado et al., 2009 for further explanation of this procedure -Appendix B-). Additional faces from the KDEF collection were used for training. The pictures were projected on the centre of the screen, subtending 20° of visual angle horizontally and vertically. This relatively large size was chosen in order to increase the possible differences between AOI and to keep constant the visual angle degrees that faces take in "personal distance" (Hall, 1966).

Participants performed one of two different tasks, expression and gender classification, on different blocks of trials of a within-subject design. The same set of images was used in both tasks and task order was counterbalanced. Analysis of gaze position was possible on account of the availability of horizontal and vertical coordinates of the gaze every 16.67 ms.

Procedure. Before starting the experiment, each participant´s right eye was calibrated by means of a nine-point calibration screen. Twenty practice trials were given before each of the two categorization tasks, using a set of KDEF faces different to that used during the actual tasks. Audio instructions, previously recorded, were given before each block. At the end of the instructions, the experimenter ensured that the participant understood the tasks and remained in the room during the experimental session.

Each trial was preceded by a 2000 ms fixation point presented on the center on the screen. The exposure time of the fixation point was enough for the pupil to return to its normal size. Target faces were presented during 1000 ms. Pupil size has been historically considered as a late response. A recent study suggests that the beginning of the changes could start before (Wang & Munoz, 2015). In order to ensure that every participant inspected the target during the same time duration, participants were asked to retain their response until the stimulus had disappeared. The next trial begun after the participant´s response or after a maximum interval of 3000 ms had elapsed. The face stimuli were presented in a random order with the restriction that two consecutive images could not belong to the same model. The inter-trial interval had 1000 ms duration. An example of the event sequence for each trial can be seen in Figure 1.

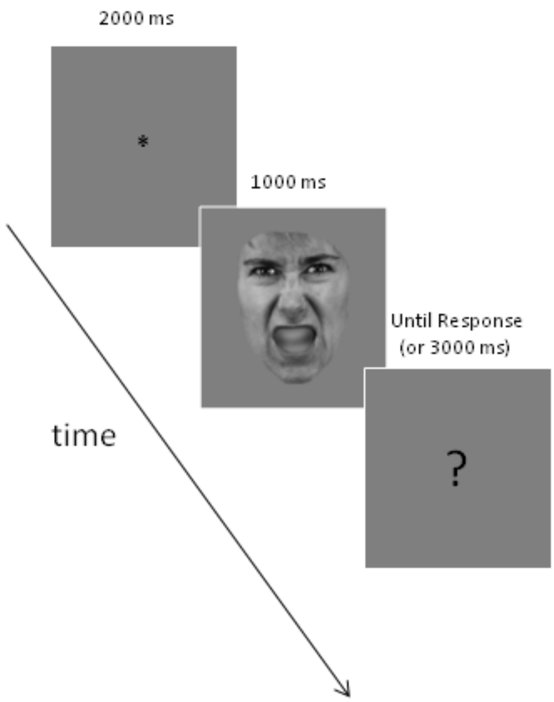

Figure 1. Trial event sequence. On different blocks of trials participants were asked to identify the gender or the emotional expression (happy or angry) of the face.

Each trial block comprised 32 trials. Participants were instructed to respond by pressing the keys associated to the corresponding response options (happy/angry in the expression task, male/female in the gender task). Different pairs of keys were assigned to each task at the same distance of the center of the keyboard.

Several parameters were considered to define a fixation. Concretely, for every fixation, a minimum of five recording data in a row were considered and three for following samples. Remember that, as it was mentioned above, the eye movement was tracked at 60 Hz (every 16.67 ms). Therefore, the minimum first sample was at least 83.35 ms. Variance of the samples was less than 1° of visual angle degree. To calculate pupil size, blinks were removed.

Data Analysis. The dependent variables included in this study were the global ocular measures (number and duration of fixations, saccadic amplitude and pupil size), ocular measures for first fixation (entry time, position and duration) and accuracy response. Given that the participants had to retain their response until the stimulus had disappeared, response time was not a reliable index and was not analyzed. Each dependent variable (except pupil size, for which the AOI was not relevant) was analyzed as a function of task, expression of the picture, gender of the picture and AOI, (upper face or eye region and lower face or mouth region). AOI were defined a priori by cutting the faces along a horizontal and imaginary line through the bridge of the nose.

A repeated measures ANOVA 2 (Task) x 2 (Expression) x 2 (Gender) x 2 (AOI) was performed for global ocular measure, except for pupil size. Besides, a repeated measures ANOVA 2 (Task) x 2 (Expression) x 2 (Gender) was carried out for pupil size, ocular measures for first fixation and accuracy response. In addition, binary comparisons between conditions were obtained controlling error type I by Bonferroni´s method. Information about the effect size is provided (partial eta square).

RESULTS

Accuracy results

Here, accuracy performance is analysed in terms of hit rate (proportion of correct answers). Significant main effects of Task were found, $F(1, 23) = 110.25$, $p < .001$, $\eta_p^2 = .83$, Expression, $F(1, 23) = 8.88$, $p = .007$, $\eta_p^2 = .28$, and Gender, $F(1, 23) = 46.64$, $p < .001$, $\eta_p^2 = .67$. Higher accuracy was observed in the emotion than in the gender task ($M = .98$ and .89, respectively). Superior accuracy was also found for happy than for angry faces ($M = .95$ and .92, respectively) and for male than for female faces ($M = .98$ and .89, respectively). A significant three-way Task x Expression x Gender interaction was obtained, $F(1, 23) = 17.84$, $p <.001$, $\eta_p^2 = .44$. Analysis of this interaction showed higher accuracy for happy than for angry female faces and for angry than for happy male faces but only in the gender task ($p_s < .001$).

Ocular variables results

The measurement of ocular variables was carried out on correct answers.

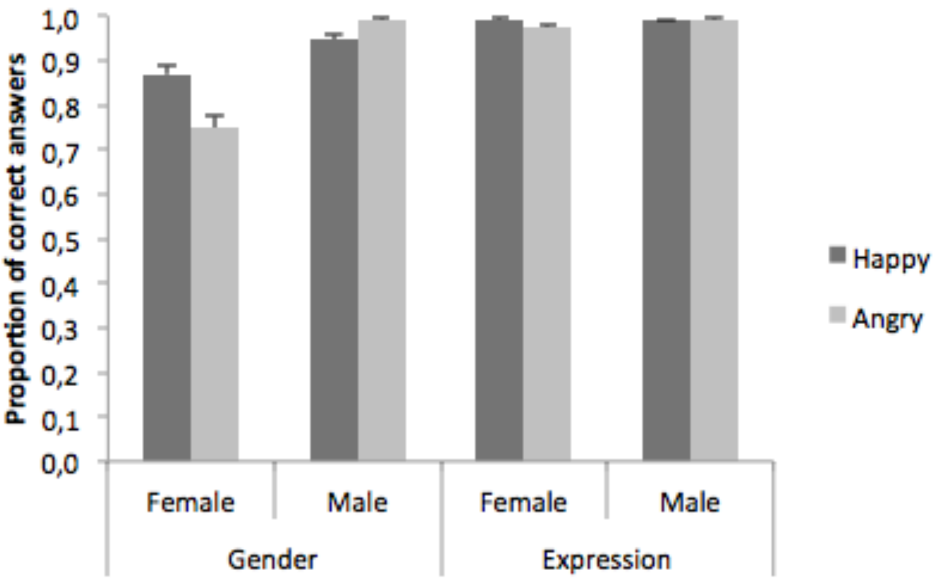

Figure 2. Accuracy in the gender and expression task.

Number of fixations

Significant main effects were found of Gender, $F(1, 23) = 14.46$, $p = .001$, $\eta_p^2 = .386$, and AOI, $F(1, 23) = 43.91$, $p < .001$, $\eta_p^2 = .65$, with increased fixations on female than on male faces ($M = .9$ and .85, respectively) and on the upper than on the lower face region ($M = 1.33$ and .41, respectively). However, the effect of gender was qualified by its interaction with task demands, as it reached significance only in the gender task, $F(1, 23) = 7.54$, $p = .011$, $\eta_p^2 = .25$. Of special relevance for the aims of this study was the significant interaction observed between Task and AOI, $F(1, 23) = 16.74$, $p < .001$, $\eta_p^2 = .42$ (see Figure 3a). Increased fixations on the eye region were observed in the gender task, compared to the expression task ($M = 1.42$ vs. 1.24, respectively, $p = .005$). Complementarily, increased fixations on the mouth region were observed in the expression task than in the gender task ($M = .52$ vs 0.31, respectively, $p = .001$). Distribution of fixations across the upper and lower face areas interacted also with Gender, $F(1, 23) = 29.47$, $p < .001$, $\eta_p^2 = .56$ and with Expression, $F(1,23) = 7.33$, $p = .013$, $\eta_p^2 = .24$. Analysis of the Gender x AOI (see Figure 3b) interaction showed significantly more fixations on the eye region of female than of male faces (1.41 vs. 1.26). Conversely, more fixations on the mouth region of male faces were observed (0.44 vs. 0.39; all p_s < .001). As to the interaction between Expression and AOI, angry faces attracted more fixations to the eye region than happy faces (1.37 and 1.3, respectively, p = .009, see Figure 3c). A non-significant trend in the opposite direction was observed for fixations on the mouth region, with increased fixation number corresponding to happy faces (happy M = .43, angry M = .39). However, this last difference reached statistical significance in the case of female faces (p = .026). Finally, a significant effect was obtained for the interaction between Gender and Expression, $F(1, 23)$ = 5.28, p = .031, η_p^2 = .19. Decomposition of this interaction showed an increased number of fixations on female -vs. male faces- only in case of those faces showing an angry expression (M = .92 and .84, for female and male faces, respectively. See Figure 3d).

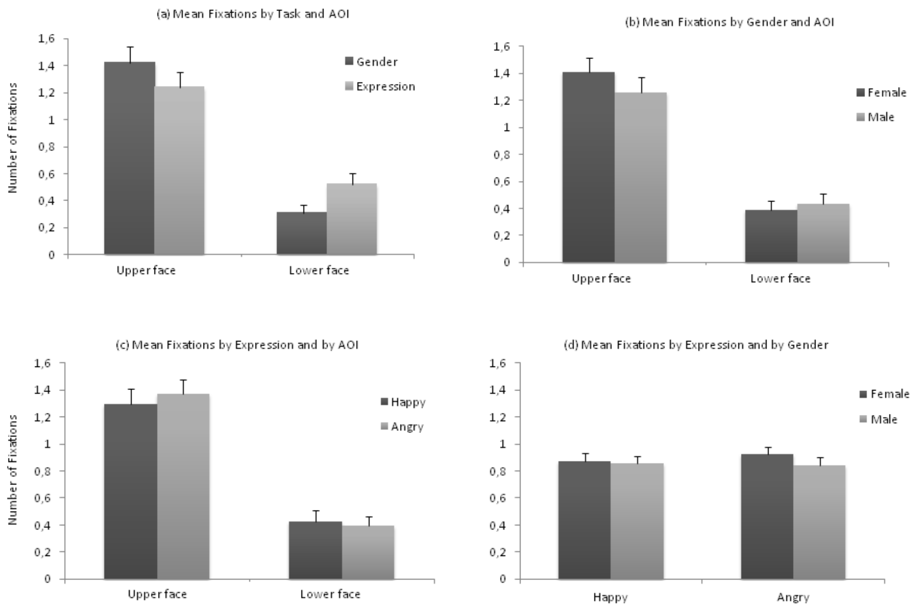

Figure 3. Fixation results according to (a) task, (b) gender, (c) expression and (d) gender/expression combination; AOI = Area of interest.

Fixation duration

Significant main effects were found of Gender, $F(1, 23) = 9.13$, $p = .006$, $\eta_p^2 = .28$, Expression, $F(1, 23) = 6.78$, $p = .016$, $\eta_p^2 = .23$, and AOI, $F(1, 23) = 16.23$, $p = .001$, $\eta_p^2 = .41$. More specifically, fixations on male faces had longer durations than those on female faces (see Figure 4a). In addition, fixations on happy faces had longer durations than those on angry faces (see Figure 4b). Fixations were also longer on the upper than on the lower face region (see Figure 4c). Finally, a significant interaction between Expression and Gender was found, $F(1, 23) = 5.17$, $p = .033$, $\eta_p^2 = .18$, with longer fixations on male faces only when they expressed anger (see Figure 4d).

Saccadic amplitude

Directly related to these results were the data obtained in *Saccadic amplitude*. In this case, a clear trend in the Task effect, $F(1, 23) = 4.03$, $p = .057$, $\eta_p^2 = .15$ was found, with increased amplitudes for expression than for gender ($M = 2.89$ and $M = 2.46$ visual angle degrees -v.a.d.-, respectively). And a three-way Task x Expression x Gender interaction, $F(1, 23) = 4.1$, $p = .05$, $\eta_p^2 = .15$ was also obtained, with a largest dispersion gaze for angry male faces ($M = 2.80$) on the expression task compared to the gender one ($M = 2.36$), $p = .021$.

Pupil Size

Results for Pupil size show significant effects of Expression, $F(1, 23) = 6.2$, $p = .02$, $\eta_p^2 = .21$, Gender, $F(1, 23) = 16.31$, $p = .001$, $\eta_p^2 = .42$, and marginally, for their interaction, $F(1, 23) = 3.94$, $p = .059$, $\eta_p^2 = .15$. Analysis of this interaction revealed larger pupil size in response to male faces when they showed an angry expression, $p < .001$ and to female faces when they showed happy expressions, $p = .003$. The results corresponding to this interaction are presented in Figure 5.

First Fixation

In order to explore the first fixation three parameters were analyzed. For *Entry time* neither simple effects of Task, Expression and Gender, (all Fs < 1), nor interactions showed significant effects (all ps $> .05$).

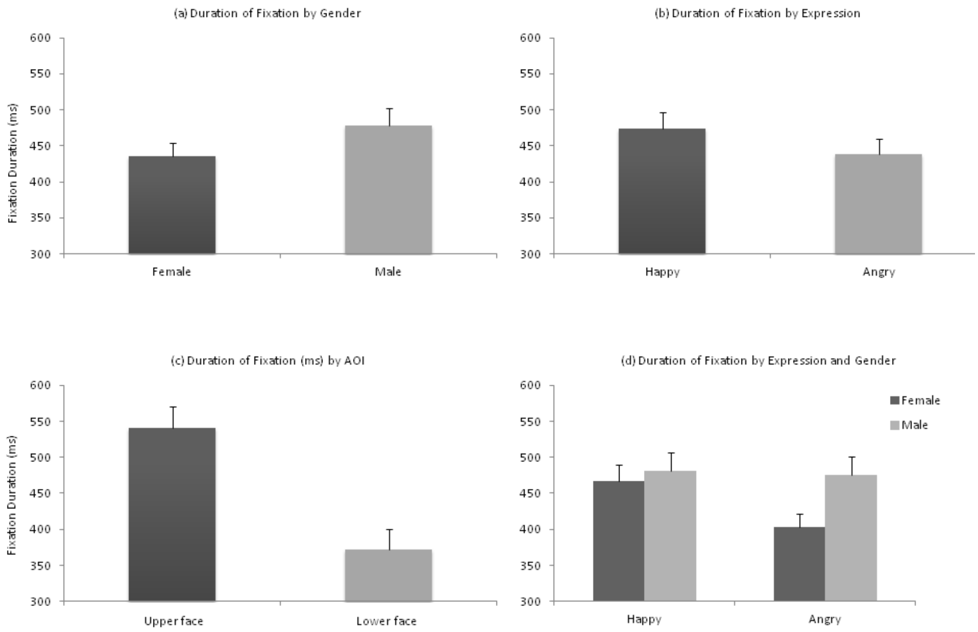

Figure 4. Fixation duration results according to (a) gender, (b) expression (c) AOI and (d) gender/expression combination.

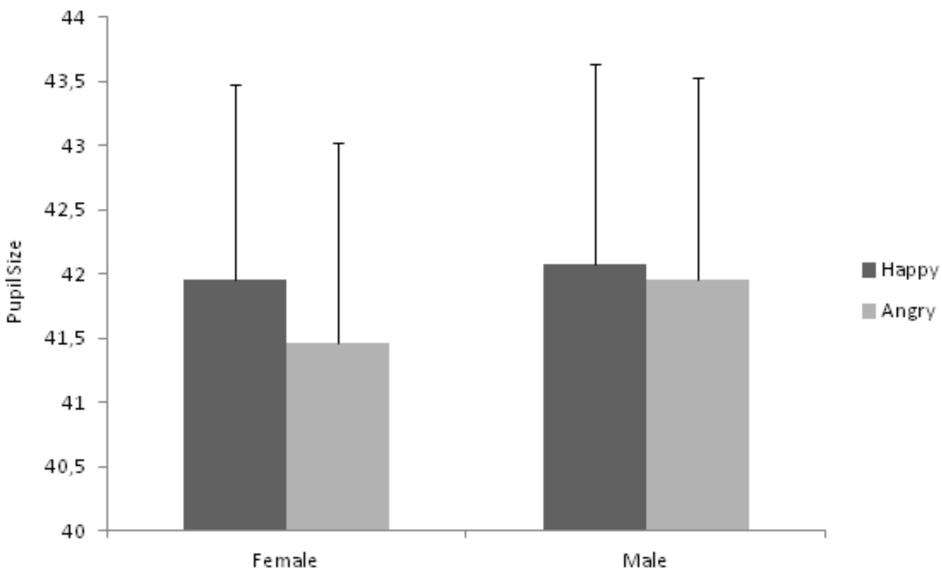

Figure 5. Pupil size in pixels (6.5 pixels equivalent to 1 mm).

Position of the first fixation was analyzed taking into account the proportion of stimuli scanned in the upper face region. In this case, we found a main effect of Task, F (1, 23) = 14.19; p = .001; η2 = .382, with a higher proportion for the Gender (*M* = .688) than for the Expression task (*M* = .581). Furthermore, we found a main effect of Gender, F (1, 23) = 25.499; p < .001; η2 = .526, with a higher proportion for female (*M* = .658) than male faces (*M* = .611). According to this analysis, a significant interaction Expression x Gender, F (1, 23) = 7.96; p = .01; η2 = .257 was also found, with a higher proportion for angry-female faces (*M* = .68) than angry-male faces (*M* = .608), *p* < .001. The results corresponding to this interaction are presented in Figure 6.

Figure 6. Proportion of stimuli looked at eye region during first fixation.

For *duration* of first fixation, we found a main effect of Task F (1, 23) = 25.499; p = .004; η2 = .308, with longer duration of first fixation for the Gender task (*M* = 544 ms) than for the Expression task (*M* = 484 ms). We also found a main effect of Expression F (1, 23) = 6.905; p = .015; η2 = .231, the first fixation being longer for happy faces (*M* = 535 ms) than for angry faces (*M* = 493 ms). Gender showed also a main effect *F* (1, 23) = 8.863; *p* = .007; η^2 = .278, with longer duration for male faces (*M* = 536 ms) than for female faces (*M* = 492 ms). Finally, the Task x Gender interaction was also significant F (1, 23) = 5.237; p < .032; η^2 = .185; only in the gender task the first fixation was longer for male (M = 579 ms) than for female faces (M = 509 ms), p = .002. The results corresponding to this interaction are presented in Figure 7.

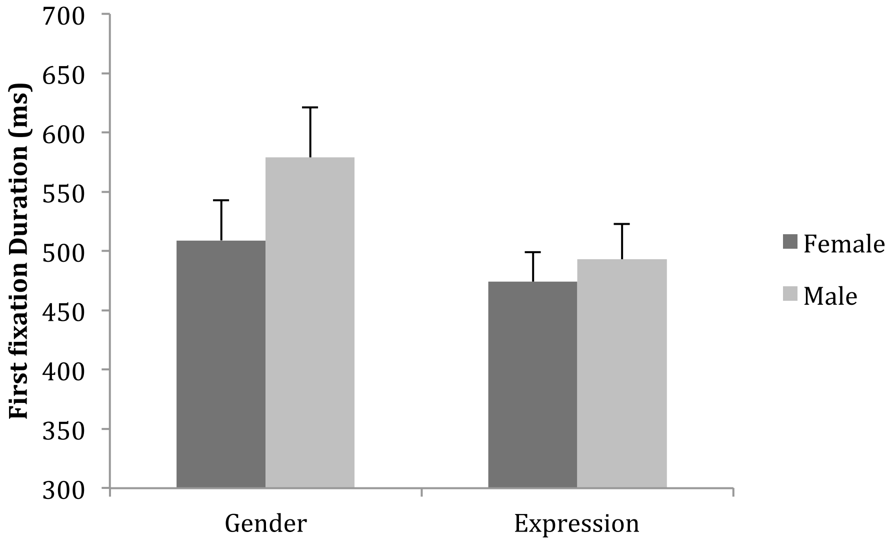

Figure 7. First fixation Duration.

DISCUSSION

Ocular variables and accuracy were measured in two different face classification tasks, expression and gender discrimination. Behavioral results indicated a superior performance on the expression task compared to the gender task. Also, a better recognition of happy versus angry faces in the expression task and better recognition of males versus females in the gender task. Moreover, an interaction of gender and expression that shows high level of accuracy for happy female faces was found; by contrast, participants identified male faces better when an angry expression was shown. According to this, previous explorations of this kind of interaction showed that happy male faces and angry female faces were more difficult to identify than angry males and happy female faces (Aguado et al., 2009; Hess, Adams, Grammer & Kleck, 2009). In defense of these results, Becker et al. (2007) proposed that anger has evolved to mimic masculinity, whereas happiness has evolved to mimic femininity.

Visual scan measures were the main dependent variables in the present study. As we mentioned in the introduction section, the number and duration of fixations are considered visual processing measures in the sense that they correspond to greater inspection and higher amount of processing. Neither of these two measures has been universally accepted as the best processing indicator. In this study, no conflict was found between these measures, except for the interaction of Gender and Expression. This means that angry female faces received a greater number of fixations and on the other hand, angry male faces received longer fixations. Future research is necessary to address this question. Considering the duration of our stimuli, the analysis of the first fixation was included because it provides powerful information of the areas preferentially attended during each task, compared to subsequent fixations. No effects on entry time were found, probably because when the stimuli appeared the observer was already looking at it.

Ocular variables were influenced by task demands and the specific nature of the stimulus in a complex manner. An overall effect of task demands was observed in the distribution of fixations -as well as in the distribution and duration of first fixation- across the upper and lower face. While the eye region attracted more frequent and longer fixations, the relative distribution of fixations on the upper and lower face was different in each task. Fixations on the upper face were more frequent in the gender task and fixations on the lower face were more frequent in the expression task. This last result is similar to that reported by Malcolm et al. (2008) in matching faces tasks in which participants had to match in terms of expression or identity. Authors reported a deep scanning of the lower face just in the expression condition. On the contrary, identity and gender discrimination rely heavily on information from the upper face (Fisher & Cox, 1975; Gosselin & Schyns, 2001; Schyns et al., 2002). Thus, the highest concentration of fixations on the upper face observed in the identity task by Malcolm et al., 2008, and in the gender task in the present experiment can be attributed to the superior diagnostic value that information from the eye region has for these tasks. Moreover, increased fixation on the lower face in the expression task is also consistent with the downward shift of preferential fixation observed in Peterson and Eckstein (2012) when the participants were asked to classify the expression of faces. Another variable that was sensitive to task demands was saccadic amplitude. The higher amplitude of saccades in the expression task, together with increased fixation on the lower face region, suggests that expression identification requires a more distributed scanning pattern across the whole face.

Differential scanning of the upper and lower face was not only determined by the type of task but also by the specific expression and gender of faces. In the case of expression task, while angry faces attracted more fixations to the eye region, happy faces tended to be scanned with more fixations on the mouth region. Happy faces also received the longest first fixation. This result is consistent with the fact that the eye and mouth regions have different informative value for the recognition of angry and happy expressions. In this regard, there is consistent evidence referring to the prevalence of the upper face for angry expressions and the lower face for happy expressions (Bassili, 1979; Calder et al., 2000; Ekman et al., 1972). On the other hand, the effects of gender have shown more fixations (including the first one) on the eye region of female faces, pointing to the female faces as the most difficult stimuli to classify. In fact, behavioral results showed that the worst gender identification is associated to female faces. Considering that the area surrounding eyes contains the richest information value for different face classification tasks, a strategy to maximize information gathering would be to increase scanning of that region when task difficulty increases.

An alternative possibility is related to the different gender information contained in the eye region since this area has already been targeted as one of the most discriminative for gender categorization tasks. In this sense, the eye-lid-brow distance, higher in females is intrinsically more salient than in males and possibly attracts automatically more attention (Campbell, Benson, Wallace, Doesbergh & Coleman, 1999; Burton, Bruce & Dench, 1993). Although smaller, differences dependent on the gender of the model were also found in scanning of the lower face. Between-gender differences in the saliency of lower face features might explain the finding that the lower face was fixated more frequently in male faces. In any case, the differences observed in the visual scanning of male and female faces indicates possible variations in the way that faces of different gender are processed. This is consistent with the suggestion derived from the study of face aftereffects that male and female faces may be coded by different neural populations (Little, DeBruine & Jones, 2005).

Interactive effects of gender and expression were found on mean fixation number and duration as well as position of the first fixation. More frequent fixations on angry female faces were observed. In these stimuli, the eye region was frequently chosen for the first fixation. Moreover, the duration of fixations on angry faces was longer only in male faces, and this pattern of results is consistent in the gender task for the duration of the first fixation. As we have already discussed, angry female faces were the most difficult to classify in terms of gender. Although in the current study, no interaction between gender and expression was found in the expression task (which must reflect an easy task or a less-interfered task, see García-Gutiérrez et al., 2015), there is previous evidence that anger is recognized more slowly from female than from male faces (Aguado et al., 2009). Thus, increased fixations on angry female faces might be indicative of a deeper or more thorough visual scanning of a stimulus that is more difficult to classify.

Furthermore, pupil size revealed also the interaction between the gender and expression of faces, with largest sizes in response to angry expressions of male faces. Complementarily, happy female faces produced an increase in pupil size compared to angry female faces. Variation in pupil size has been used in several studies as an index or processing load (e.g., Beatty, 1982; Hyönä, 1995; Granholm, Asarnow, Sarkin, & Dykes, 1996; Kahneman & Beatty, 1966; van Gerven, Paas, van Merriënboer & Schmidt, 2004) and there is also evidence that emotional arousal is a key factor controlling this response (Bradley et al., 2008). An interpretation in terms of the cognitive effort employed in processing load is not consistent with our results. The pupil size in response to female faces was significantly larger for happy than for angry faces. However, the less accurate gender categorization of angry female faces indicates that these faces, and not the happy ones, were the most difficult to classify and, consequently, required greater cognitive effort. A similar reasoning can be applied considering that pupil size in response to angry female faces was also smaller than that corresponding to angry male faces. In this case, there was also an inverse relationship between classification difficulty and pupil size. If differences in processing load cannot explain these variations in pupil size, then they might be attributed to different levels of arousal produced in response to specific combinations of gender and emotional expression. Specifically, this explanation would suggest that stimuli eliciting higher arousal levels could be angry male and happy female faces. This variation in the emotional impact of happy and angry facial expressions shown by male and female faces seems consistent with the proposal that response to these expressions is mediated by the differential attribution of dominance and affiliativeness to men and women (Hess et al., 2005). While there was a correspondence between behavioral and eye movement results, no such correspondence was found between behavioral and pupil size data. We suggest that pupil size reflects an interaction based on differences in the affective properties of the faces, while behavioral and eye movement results reveal an interaction based on mechanisms of a perceptual nature, e.g., as the covariation of features relevant for both gender and expression discrimination.

Finally, we should mention some aspects of the present study that might limit the generalization of our conclusions. On one hand, the set of faces used in our study were constrained to two emotional expressions (anger and happy), and as was pointed out in the introductory section, there are considerable differences in terms of the relative weight of the upper and lower face in different emotional expressions (Bassili, 1979; Calder et al., 2000; Ekman et al., 1972). In fact, the present study showed differences in fixation on the upper and lower face between happy and angry expressions. Thus, it is likely that visual scanning will be differentially modulated when presenting faces showing other emotional expressions. Concerning the size of stimuli, we are aware that this issue could decrease the ecological validity but as we mentioned above, the large size was chosen in order to increase the possible differences between AOI. In this study, the mouth area was blurred (see Appendix) in order to avoid the saliency and the detection advantage of happy faces because of their white teeth and not because of the contrast or luminance (see Calvo & Nummenmaa, 2008). Furthermore, these authors showed differential facilitation effect of the teeth between expressions. According to this, Peterson and Eckstein (2012) showed similar results in gender and expression tasks in terms of location of fixations. Moreover, these authors suggest that the area below the eyes is the most important one from which the visual human system optimizes face recognition performance. In these particular tasks, the ocular movements tend to scan the middle of the face area rather than other areas so this explanation rule out the idea about the limitations of external validity supposedly introduced by the blurred teeth manipulation. Moreover, participants in this study were mostly females and this fact limits to this sample the generalization of our results.

Heisz, Pottruff and Shore (2013) found that females were more accurate than males in recognition face task. Aguado et al. (2009) did not find such differences. Hence, for more definitive conclusions, we must await for future research with samples balanced in terms of gender and a larger variety of facial expressions. However, regardless of the limitation, we still believe that our study contributes towards a better understanding of how our visual scanning system works.

To sum up, results in the current study revealed that visual scanning of faces showing emotional expressions is determined by task demands and by the perceptual and affective characteristics of faces. Modulation of visual behavior reflected the relative contribution of information from the upper and lower face to the discrimination of gender and expression. This modulation indicates that the specific goals of the observer are decisive to determine visual behavior when looking at a human face. However, some specific aspects of visual scanning reflect perceptual interactions suggesting that gender and expression categorizations are not completely dissociable. Variations in pupil size also revealed interactions of gender and expression which seem to be more related to differences in affective value and social categorization.

RESUMEN

Dónde mirar cuando miramos caras: el escaneo visual está determinado por el género, la expresión y las demandas de la tarea. Se ha estudiado la inspección visual de caras durante tareas de categorización de expresión y género con el objetivo de encontrar posibles diferencias en los mecanismos perceptuales que medían el análisis de las propiedades faciales. Se observó un patrón de inspección visual más distribuido con un incremento de fijaciones en la parte baja de la cara durante la tarea de expresión frente a la tarea de género. La distribución de las fijaciones en torno a la parte superior e inferior de la cara también varió dependiendo del género y de la expresión de las caras con un número mayor de fijaciones en la región de los ojos para las caras de ira femeninas. Los resultados indicaron también una interacción entre género y expresión. La naturaleza de estas modulaciones sugiere una influencia diferencial sobre las medidas oculares y el tamaño de la pupila dependientes del tipo de tarea y del valor socio-afectivo de los estímulos. En conjunto, estos resultados muestran que la inspección visual de caras está determinada de una manera compleja por las demandas específicas de diferentes tareas de categorización; por las propiedades perceptivas y por la naturaleza de las expresiones emocionales mostradas por caras masculinas y femeninas.

REFERENCES

Aguado, L., García-Gutiérrez, A., & Serrano-Pedraza, I. (2009). Symmetrical interaction of sex and expression in face classification tasks. *Attention, Perception & Psychophysics, 71,* 9-25.

Aguado, L., Serrano-Pedraza, I., & García-Gutiérrez, A. (2014). A comparison of backward masking of faces in expression and gender identification tasks. *Psicológica*, *35*, 171-194

Atkinson, A. P., Tipples, J., Burt, D. M., & Young, A. W. (2005). Asymmetric interference between sex and emotion in face perception. *Perception & Psychophysics*, *67*, 1199-1213.

Barton, J., Radcliffe, N., Cherkasova, M., Edelman, J., & Intriligator, J. (2006). Information processing during face recognition: The effects of familiarity, inversion, and morphing on scanning fixations. *Perception, 35*, 1089-1105.

Bassili, J. (1979). Emotion recognition: The role of facial movement and the relative importance of upper and lower areas of the face. *Journal of Personality and Social Psychology, 37*, 2049-2058.

Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology*, *45*, 602-607.

Beatty, J. (1982). Task-Evoked pupillary responses, processing load, and the structure of processing resources. *Psychological Bulletin, 91*, 276-92.

Becker, D. V., Kenrick, D. T., Neuberg, S. L., Blackwell, K.C., & Smith, D. S. (2007). The confounded nature of angry men and happy women. *Journal of Personality and Social Psychology, 92,* 179–190.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British journal of psychology, 77*(3), 305-327.

Buchan, J. N., Paré, M., & Munhall, K. G. (2007). Spatial statistics of gaze fixations during dynamic face processing. *Social Neuroscience*, *2*(1), 1-13.

Burton, A. M., Bruce, V., & Dench, N. (1993). What's the difference between men and women? Evidence from facial measurement. *Perception, 22*,153-176.

Caldara, R., Zhou, X., & Miellet, S. (2010). Putting culture under the 'Spotlight' reveals universal information use for face recognition. *PLoS ONE*, *5*: e9708.

Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human Perception and Performance, 26*, 527-551.

Calvo, M. G., & Nummenmaa, L. (2008). Detection of emotional faces: salient physical features guide effective visual search. *Journal of Experimental Psychology: General, 137,* 471-494.

Campbell, R., Benson, P. J., Wallace, S. B., Doesbergh, S., & Coleman, M. (1999). More about brows: How poses that change brow position affect perceptions of gender. *Perception-London, 28*(4), 489-504.

Duchowski, A. T. (2002). A breadth-first survey of eye-tracking applications. *Behavior Research Methods, Instruments, & Computers, 34*, 455-470.

Ekman, P., Friesen, W. V., & Ellsworth, P. (1972). *Emotion in the human face: guide-lines for research and an integration of findings*. New York: Pergamon Press.

Ekman, P., & Friesen, W. (1978). *Facial Action Coding System: A technique for the measurement of facial movement*. Palo Alto, California: Consulting Psychologists Press.

Fisher, G., & Cox, R. (1975). Recognizing human faces. *Applied Ergonomics, 6,*104-109.

García-Gutiérrez, A., Aguado, L., Romero-Ferreiro, M. V. & Pérez-Moreno, E. (2015). Discrimination of face gender and expression under dual task conditions. Manuscript submitted for publication.

Gosselin, F., & Schyns, P. G. (2001). Bubbles: A technique to reveal the use of information in recognition. *Vision Research*, *41*, 2261-2271.

Granholm, E., Asarnow, R. F., Sarkin, A. J., & Dykes, K. L. (1996). Pupillary responses index cognitive resource limitations. *Psychophysiology, 33*, 457–461.

Green, M. J., Williams, L. M., & Davidson, D. J. (2003a). In the face of danger: specific viewing strategies for facial expressions of threat. *Cognition & Emotion*, *17*, 779-786.

Green, M. J., Williams, L. M., & Davidson, D. J. (2003b). Visual scanpaths and facial affect recognition in delusion-prone individuals: Increased sensitivity to threat? *Cognitive Neuropsychiatry*, *8*, 19-41.

Hall, E. T. (1966). *The hidden dimension*. New York: Doubleday.

Hall, J. K., Hutton, S. B. & Morgan, M. J. (2010) Sex differences in scanning faces: Does attention to the eyes explain female superiority in facial expression recognition? *Cognition & Emotion, 24*, 629-637.

Henderson, J. M. (2003). Human gaze control during real-world scene perception. *Trends in Cognitive Sciences, 7*, 498–504.

Henderson, J. M., Williams, C.C. & Falk, R. J. (2005). Eye movements are functional during face learning. *Memory & Cognition, 33*, 98-106.

Hess, U., Adams, R. B., Jr., Grammer, K., & Kleck, R. E. (2009). Face, gender and emotion expression. Are angry women more like men? *Journal of Vision, 9,* 19, 1-8.

Hess, U., Adams, R. B. Jr., & Kleck, R. E. (2005). Who may frown and who should smile? Dominance, affiliation, and the display of happiness and anger. *Cognition & Emotion, 19*, 515-536.

Hess, U., Adams Jr, R. B., & Kleck, R. E. (2007). Looking at you or looking elsewhere: The influence of head orientation on the signal value of emotional facial expressions. *Motivation and Emotion, 31(2),* 137-144.

Hess, U., Adams, R. B. Jr., & Kleck, R. E. (2009). The face is not an empty canvas: How facial expressions interact with facial appearance. *Philosophical Transactions of the Royal Society London B, 364*, 3497-3504

Heisz, J. J., Pottruff, M. M., & Shore, D. I. (2013). Females scan more than males: a potential mechanism for sex differences in recognition memory. *Psychogical Science, 24*, 1157-1163.

Hoffman, J. E. (1998). *Visual attention and eye movements*. In H. Pashler (ed.), Attention (pp. 119–154). Hove, UK: Psychology Press.

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & Van de Weijer, J. (2011). *Eye tracking: A comprehensive guide to methods and measures*. New York, NY: Oxford University Press.

Hugenberg, K., & Sczesny, S. (2006). On Wonderful Women and Seeing Smiles: Social Categorization Moderates the Happy Face Response Latency Advantage. *Social Cognition*, *24*, 516-539.

Hyönä, J. (1995). An eye movement analysis of topic-shift effect during repeated reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 1365-1373.

Jacob, R. J., & Karn, K. S. (2003). Eye tracking in human-computer interaction and usability research: Ready to deliver the promises. *Mind, 2*(3), 4.

Kahneman, D., & Beatty, J. (1966). Pupil diameter and load on memory. *Science, 154*, 1583-1585.

Kawamura, S., Komori, M., & Miyamoto, Y. (2008). Smiling reduces masculinity: principal component analysis applied to facial images. *Perception, 37*, 1637-1648.

Leigh, R. J., & Zee, D. S. (1999). *The neurology of eye movements* (Vol. 90). New York: Oxford University Press.

Little, A. C., DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society of London B: Biological Sciences, 272*(1578), 2283-2287.

Lundqvist, D., Esteves, F., & Öhman, A. (1999). The face of wrath: critical features for conveying facial threat. *Cognition & Emotion, 13,* 691–711.

Lundqvist, D. & Litton, J. E. (1998). *The Averaged Karolinska Directed Emotional Face – AKDEF*. CD ROM from Department of Clinical Neuroscience, Psychology section, Karolinska Institutet, ISBN 91-630-7164-9.

Malcolm, G. L., Lanyon, L. J., Fugard, A. J. B., & Barton, J. J. S. (2008). Scan patterns during the processing of facial expression versus identity: An exploration of task-driven and stimulus-driven effects. *Journal of Vision, 8*, 1-9.

Mäntylä, T., & Holm, L. (2006). Gaze control and recollective experience in face recognition. *Visual Cognition, 13*, 365-386.

Matsumoto, D. (1989). Face, culture, and judgments of anger and fear: do the eyes have it? *Journal Nonverbal Behavior, 13*, 171–88.

Oosterhof, N. N. & Todorov, A. (2008). The functional basis of face evaluation. *Proceedings of National Academy of Science of USA, 105*, 11087–11092

Peterson, M. F., & Eckstein, M. P. (2012). Looking just below the eyes is optimal across face recognition tasks. *Proceedings of the National Academy of Sciences*, *109*, E3314-E3323.

Rayner, K. (2009). Eye movements and attention in reading, scene perception, and visual search. *The Quarterly Journal of Experimental Psychology, 62*, 1457–1506.

Schyns, P. G., Bonnar, L., & Gosselin, F. (2002). Show me the features! Understanding recognition from the use of visual information. *Psychological Science*, *13*, 402-409.

Smith, M. L., Cottrell, G. W., Gosselin, F., & Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychological Science, 16*, 184-189.

Tamietto, M., Castelli, L., Vighetti, S., Perozzo, P., Geminiani, G., Weiskrantz, L., & de Gelder, B. (2009). Unseen facial and bodily expressions trigger fast emotional reactions. *Proceedings of the National Academy of Sciences of the United States of America, 106*, 17661-17666.

van Gompel, R., Fischer, M., Murray, W. & Hill, R. (Eds.) (2007). *Eye Movements: A Window on Mind and Brain*. Amnsterdam: Elsevier

Vassallo, S., Cooper, S. L. C., & Douglas, J. M. (2009). Visual scanning in the recognition of facial affect: Is there an observer sex difference? *Journal of Vision, 9,* 1-10.

van Gerven, P. W., Paas, F., van Merriënboer, J. J. & Schmidt, H. G. (2004). Memory load and the cognitive pupillary response in aging. *Psychophysiology*, *4*, 167-174.

Wang, C. A., & Munoz, D. P. (2015). A circuit for pupil orienting responses: implications for cognitive modulation of pupil size. *Current Opinion in Neurobiology*, *33*, 134-140.

APPENDIX

Pictures Used in this Experiment

Picture	Collection	Expression	Sex	Blurring
AF06HAS	KDEF	Happy	F	YES
AF07ANS	KDEF	Angry	F	YES
AF07HAS	KDEF	Happy	F	YES
AF09HAS	KDEF	Happy	F	YES
AF11HAS	KDEF	Happy	F	YES
AF20HAS	KDEF	Happy	F	YES
AF21ANS	KDEF	Angry	F	NO
AF21HAS	KDEF	Happy	F	YES
AF31ANS	KDEF	Angry	F	YES
AF35ANS	KDEF	Angry	F	YES
AF35HAS	KDEF	Happy	F	YES
AM03ANS	KDEF	Angry	M	NO
AM08ANS	KDEF	Angry	M	YES
AM08HAS	KDEF	Happy	M	YES
AM09ANS	KDEF	Angry	M	NO
AM09HAS	KDEF	Happy	M	YES
AM10ANS	KDEF	Angry	M	YES
AM10HAS	KDEF	Happy	M	YES
AM15HAS	KDEF	Happy	M	YES
AM17ANS	KDEF	Angry	M	YES
AM17HAS	KDEF	Happy	M	YES
AM23ANS	KDEF	Angry	M	NO
AM23HAS	KDEF	Happy	M	YES
BF06ANS	KDEF	Angry	F	YES
BF09ANS	KDEF	Angry	F	NO
BF11ANS	KDEF	Angry	F	NO
BF20ANS	KDEF	Angry	F	NO
BF31HAS	KDEF	Happy	F	YES
BM03HAS	KDEF	Happy	M	YES
BM04ANS	KDEF	Angry	M	NO
BM04HAS	KDEF	Happy	M	YES
BM15ANS	KDEF	Angry	M	YES

(Manuscript received: 8 October 2014; accepted: 22 December 2015)