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Relationship between facial attractiveness and pupil diameter in young adults

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Abstract

The objective of this study was to investigate whether there is a relationship between pupil diameter and facial attractiveness. Participated in the study 60 young adults (30 men and 30 women) between 18 and 26 years of age (M=20.65, SD=2.20). Ten different unfamiliar neutral faces (five men and five women) were used as stimuli. The pupil diameter of each face was manipulated with pupil diameters of 2, 3, 4, 5 and 6 mm (10 faces x 5 pupil diameters = 50 stimuli). A two-step study was carried out with the same sample and the same sets of faces, seeking to understand the difference of responses between subjects of both sexes. In phase I, result indicated a significant difference in relation to the pupil diameter factor for both the men ($\chi^2 = 21.93$, $p < .05$) and the women ($\chi^2 = 44.73$, $p < .05$). In phase II, the results indicated significant differences in relation to the pupil size [$F(1, 234) = 19.06$, $p < 0.05$]. The post-hoc Tukey HSD test showed that both the men and the women differently judged the faces with a pupil diameter of 2 mm in relation to the faces with pupil diameters of 3, 4, 5 and 6 mm ($p < .05$). Also, a significant difference between the diameter of 5 mm in relation to the diameter of 3 mm ($p < .05$). In general, the results indicate that the pupil diameter is a structural component of the human face that plays an important role in the process of judging facial attractiveness.

Keywords: pupil diameter; facial attractiveness; young adults.

Relação entre a atratividade facial e diâmetro pupilar em adultos jovens

Resumo

O objetivo deste estudo foi investigar a relação entre o diâmetro da pupila e a atratividade facial. Participaram da pesquisa 60 jovens com idade entre 18 e 26 anos. Foram utilizadas dez faces de adultos jovens, manipulou-se o diâmetro de cada pupila com variações de 2, 3, 4, 5 e 6 mm. Realizou-se um estudo em duas etapas: na fase I, o resultado indicou diferença significativa para o fator de diâmetro pupilar tanto para homens quanto para mulheres ($p < 0,05$). Na fase II, os resultados indicaram diferenças significativas em relação ao tamanho da pupila ($p < 0,05$). O teste *post-hoc* Tukey mostrou que tanto os homens quanto as mulheres avaliaram diferentemente as faces com diâmetro pupilar de 2 mm ($p < 0,05$). Em geral, os resultados indicam que o diâmetro da pupila é um componente da face humana que desempenha um importante função no processo de julgamento da atratividade facial.

Palavras-chave: diâmetro da pupila; atratividade facial; adultos jovens.

Relación entre atratividad facial y diámetro de la pupila en adultos jóvenes

Resumen

El objetivo de este estudio fue investigar si existe una relación entre el diámetro pupilar y el atractivo facial. Participaron en la estudio 60 adultos jóvenes (30 hombres y 30 mujeres) entre 18 y 26 años de edad (M=20.65, DE=2.20). Se utilizaron como estímulos diez rostros neutrales desconocidos diferentes (cinco hombres y cinco mujeres). El diámetro de la pupila de cada cara se manipuló con diámetros de pupila de 2, 3, 4, 5 y 6 mm (10 caras x 5 diámetros de pupila = 50 estímulos). Se realizó un estudio en dos etapas con la misma muestra y los mismos conjuntos de caras buscando entender la diferencia de respuestas entre sujetos de ambos sexos. En la fase I, el resultado indicó una diferencia significativa en relación al factor de diámetro de la pupila tanto para los hombres ($\chi^2 = 21.93$, $p < 0.05$) como para las mujeres ($\chi^2 = 44.73$, $p < 0.05$). En la fase II, los resultados indicaron diferencias significativas en relación al tamaño de la pupila [$F(1, 234) = 19,06$, $p < 0,05$]. La prueba *post-hoc* de Tukey HSD mostró que tanto los hombres como las mujeres evaluaron de manera diferente las caras con un diámetro pupilar de 2 mm con respecto a las caras con diámetros pupilares de 3, 4, 5 y 6 mm ($p < 0,05$). Se observó una diferencia significativa entre el diámetro de 5 mm en relación al diámetro de 3 mm ($p < 0,05$). En general, los resultados indican que el diámetro de la pupila es un componente estructural de la cara humana que desempeña una importante función en el proceso de juicio del atractivo facial.

Palabras clave: diámetro pupilar; Atractivo facial; adultos jovene.

The ability to assess facial attractiveness has been related to the ability to judge facial features and expressions (Holand, 2002). Studies that use faces as visual stimuli have demonstrated the cognitive process used in the recollection and coding of global and analytic aspects of the face (Perrett, May, & Yoshikawa, 1994; Rosenthal, Sack, & Gillin, 1984; Terry & Davis, 1976). In analytical processing, the elements analyzed are generally related to ocular structures, such as the configuration (Omote, 1999) and position of the eyes (Brooks & Hochberg, 1960), visual correction (Terry & Brady, 1976), and pupil diameter (Demos, Kelly, Ryan, & Whalen, 2008; Hess, 1965; Hess & Polt, 1960).

The pupil is an essential structure for the functioning of the visual system, such that the diameter or size can affect, for example, the light that hits the retina and the optical transfer function of the eye (Watson & Yellott, 2012), thus directly interfering in visual perception. In humans, the pupil has a symmetrically circular format, with a diameter that can vary between 2 and 8 mm (Watson & Yellott, 2012) or even between 1.5 and 8 mm, depending on the stimulus (Shunke, Schulte, Schumacher, Voll, & Wesker, 2007).

A few studies have sought to understand the relationship between facial attractiveness and pupil diameter (Demos et al., 2008; Hagerman, Woolard, Anderson, Tatler, & Moore, 2017; Hess & Polt, 1960; Hess, 1965; Tombs & Silverman, 2004). However, it is understood that facial elements, such as the pupil, are primary elements for the formation of visual perception and respectively social interaction. The first studies to investigate the existence of a relationship between pupil diameter and attractiveness were conducted in the 1960s (Hess & Polt, 1960; Hess, 1965). In 1960, Hess and Polt measured the pupil diameter of six men and women during the observation of visual stimuli (photos of babies, a mother holding a child, a partially nude man, a partially nude woman, and a landscape scene). The results showed an increase in the diameter of the pupil, which was related to the attractiveness according to the type of stimulus (male and female nude pictures) and the participant's sex. In 1965, Hess evaluated the relationship between pleasant (attractive) and unpleasant (unattractive) stimuli and pupil diameter. The results were similar to those found in the previous study. Thus, Hess showed that the pupils of young women were dilated in the presence of photographs of mothers holding a child and that the pupils of both women and men contracted in the presence of photographs of older adults or disabled children. Additionally, when presented to the opposite sex, photographs of women and men produced greater pupil dilation. According to Partala, Jokiniemi, and Surakka (2000), pupil size detection correlates with the variation of the presented stimulus.

Tombs and Silverman (2004) investigated the variation of the detection of the pupil diameter of masculine and feminine faces judged to be subjects of both male and female sex. The responses of masculine subjects presented a linear function with a preference for large pupils. On the other hand, the women presented responses in the form of an inverted U function with a preference for medium pupils. According to authors, men and women probably present different strategies of action as a tool for sexual interest. Studies have investigated the responses to the interests of variation or pupil diameter in men and women, however, they have shown inconsistent results (Bull & Shead, 1979, Hicks, Pellegrini, & Tomlinson, 1978). Furthermore, the pupil diameter preference for women may be related to the ovulation process and reproductive tactics, showing that responses to perception of large pupils in males are significantly stronger during the follicular phase of the menstrual cycle in which they are sexually excitable (Caryl, Bean, Smallwood, Barron, Tully, & Allerhand, 2009).

Demos et al. (2008) investigate whether the amygdala is sensitive to variations in the pupil size of others. These researchers use event-related functional magnetic resonance imaging (fMRI) of male and female unfamiliar faces with pupil diameters ranging between 2.36 and 3.44 mm as stimuli. The results reveal that the right and left amygdala of the males were sensitive to variation in the pupil size of the females, i.e., the larger the pupil diameter, the greater the functional activity of the amygdala. The authors suggest that the amygdala is involved in the detection of changes in pupil size, exerting a signal of arousal and/or interest even in the absence of explicit knowledge of the manipulation of the pupil. In a similar study, Amemiya and Ohtomo (2012) use event-related fMRI to investigate the role of the amygdala in the detection of pupil size variation, taking into account the effect of sex and attractiveness. The results indicate a greater activation of the amygdala for large pupils, independent of sex, and the differences in activation are independent of the perceived attractiveness. According to the authors, the results support the idea that the amygdala is sensitive to explicit or implicit fear, abhorrence, preference and the vigilance of aversive stimuli. Still, Hagerman et al. (2017) point out that amygdala may possess a physiological role excitation attractiveness.

In general, the diameter of the pupil can be utilized as a variable for measures of facial attractiveness, the responses can change according to the subject's perception of in relation your sex and the facial stimuli's sex (Lick, Cortland, & Johnson, 2016). The

objective of present study is to investigate whether there is a relationship between the manipulation of pupil diameter and the judgment of facial attractiveness of men and women, using behavioral research designs and the manipulation of the pupil diameter of neutral unfamiliar faces of men and women. The hypothesis, based on the behavioral studies in the literature (e.g., Hess & Polt, 1960; Hess, 1965), is that is an interaction effect between the pupil diameter and the facial attractiveness of men and women exposed to faces of the opposite sex. In other words, it is expected that neutral faces with large pupil diameters will be more attractive (Caryl et al., 2009; Tombs & Silverman, 2004). This hypothesis is tested in two phases in the study with different methods, using the same sample and manipulations of pupils of the same neutral faces, in an attempt to isolate only the function of the pupil in the tasks involving the judgment of facial attractiveness.

Method

Participants

The initial sample had 70 volunteers; however, 10 volunteers (five men and five women) were not included because they did not meet the inclusion criteria. Thus, 60 young adults (30 men and 30 women) from 18 to 26 years old (M = 20.65; SD = 2.20) and from different undergraduate programs of the same university participated in the study. Inclusion criteria were all of the participants had normal or corrected 20/20 visual acuity and were healthy and exclusion criteria were the use of drugs or psychoactive substances. All of the volunteers were unfamiliar with the study and had an up-to-date fundus examination, with no eye disease evident. Of these volunteers, 23.3% were from the Psychology program, 11.6% from the Food Engineering program, and 10% from the Mechanical Production Engineering and Social Sciences programs. First-semester students were the most represented (36.6%). Most of the volunteers were single (96.6%), Catholic (61.6%), and white (51.6%), and most had a family income of between USD 720 and 1,874 (63.6%).

Instruments and Equipment

The following were used: (a) a socio-demographic questionnaire to record answers related to the characteristics of the sample; (b) Rasquin's "E" optotype for measuring visual acuity; (c) a 19-inch LG RGB monitor with a resolution of 1024 × 768 pixels at 75 Hz for the presentation of the facial stimuli; (d) an OptiCAL digital photometer (Cambridge Research Systems) to measure the luminance of the monitor; (e) a visual analogue scale (VAS) – a 10 cm horizontal line with the left and right extremes corresponding to "not at all attractive" and "extremely attractive", respectively, for measuring the perception of the level of attractiveness based on the facial stimuli; and (f) Psycoface, a software program written in C++ that was developed by the laboratory itself to perform experiments on emotions, facial expressions, and facial attractiveness according to pupil diameter.

Stimuli

Ten neutral unfamiliar faces (in color) of different people (five heterosexual men and five heterosexual women) were used. The pupil diameter of each face was altered to five different sizes (2, 3, 4, 5, and 6 mm) using Adobe Photoshop CS2 software. Thus, a total of 50 faces – 25 male faces and 25 female faces – was generated. The faces were standardized and displayed at a size of 256 × 256 pixels on a monitor with an average luminance of 42 cd/m² (**Figure 1**).

Figure 1. Simulation of the set of stimuli with female and male faces, varying only the pupil size. From top to bottom: real stimulus with 2 mm pupils (face shown originally at a size of 256 × 256 pixels); cropped face with 2 mm pupils; cropped face with 4 mm pupils; and cropped face with 6 mm pupils.

Procedure

A study of the experimental design of repeated measures was carried out. All of the volunteers completed a socio-demographic questionnaire and had their visual acuity tested with Rasquin's "E" optotype to ascertain whether visual acuity was normal or corrected.

Two experiments were performed using a research design with repeated measures in which all of the volunteers participated. The effect of the order between the two experiments was controlled using the counterbalancing technique; thus, half of the volunteers started in Experiment I and the other half in Experiment II, and then they changed over.

Ethical aspects

This study complied with all of the precepts recommended by resolution nº 196/12 of the National

Health Council of the Brazilian Ministry of Health, which addresses the guidelines and standards of research involving human subjects. All of the participants signed an informed consent form, in which the objectives of the study were stated and the agreement to participate in the research was recorded. This study was approved by the Research Ethics Committee of the Health Sciences Center of the affiliated institution, under protocol nº 0041.

Phase I. Choosing the most attractive face

In this phase, each participant had to choose the most attractive face from each set of five unfamiliar faces of the opposite sex. The sets of faces were organized in blocks according to the diameter of the pupil, a total of 10 sets of faces were presented. The faces from each set were presented in a simple, random, and successive manner on the monitor screen. To facilitate the recording of the response, each face was associated with a letter of the alphabet. The choice of the most attractive face was made by clicking on the letter corresponding to the face selected as the most attractive, and then, the program changed to another set of faces, and so on, until each participant had gone through the five sets, such that the men were tested with the female faces and the women were tested with the male faces. If the volunteer had any doubt in choosing the most attractive face in any of the sets, the set could be presented more than once by clicking the "repeat" button, which would appear at the end of the presentation of each set of faces. The presentation time for each face was 3000 ms, and the interval between the presentation of one face and another was 2000 ms. In total, for each male volunteer and each female volunteer, 25 faces of the opposite sex (five sets of five faces with unfamiliar female or male faces) were presented.

Phase II. Individual judgment of the attractiveness of the faces

In this study, the VAS – a 10 cm horizontal line with left and right extremes corresponding to "not at all attractive" and "extremely attractive", respectively – was used so that the participant could indicate, with a vertical line along the horizontal line, how attractive each face was or the attractiveness score in relation to each of the 25 faces of the opposite sex displayed. The rest of the procedure for phase II was the same as that of phase I.

Data analysis

The responses of the volunteers were grouped into spreadsheets, and the data were analyzed using descriptive and inferential statistics to verify the existence of a relationship between the pupil diameter and the response or the attribution of the degree of facial attractiveness.

Results

In Phase I the number of responses attributed to each of the faces chosen from each set as being the most attractive was assessed. **Table 1** shows the frequency of the attribution of attractiveness for the neutral faces with the five manipulated pupil diameters (2, 3, 4, 5, and 6 mm). The male participants presented greater attractiveness to female faces (5 mm, 30.66%, 4 mm, 26%, and 6 mm, 19.33%, 2 mm, 9.33%). Similarly, the female participants judged male faces with a 4 mm (38.67%), 5 mm (25.33%), and 6 mm (12.67%) pupil diameter as being more attractive, whereas male faces with a 2 mm diameter (8%) were considered to be less attractive. The neutral female and male faces with the three largest pupil diameters obtained 76% of the responses from the men and 76.7% of the responses from the women – the most frequent response from the men was for the female face with a 5 mm pupil diameter (30.66%), whereas the most frequent response from the women occurred for the male face with the 4 mm pupil diameter (38.67%). The Mann-Whitney test showed a significant difference for the group factor ($p < 0.05$), which indicates that the men and women responded differently when choosing the most attractive face. Regarding the pupil factor, the chi-square test showed a significant difference for both the men's group ($\chi^2 = 21.93$, $p < 0.05$) and the women's group ($\chi^2 = 44.73$, $p < 0.05$). This finding implies that neutral faces with variations in pupil sizes tend to be judged differently, although this judgment varies by gender. The data indicate men tend to judge greater attractiveness in female faces for pupils with a diameter of 5 mm since women are judging more attractiveness on 4mm diameter masculine faces.

TABLE 1
Frequency of choice of neutral faces by men and women according to different pupil diameters (Experiment 1)

	Men		*Women*	
Diameter	*N. of responses*	*%*	*N. of responses*	*%*
2 mm	14	9.33	12	8
3 mm	22	14.66	23	15.33
4 mm	39	26	58	38.67
5 mm	46	30.66	38	25.33
6 mm	29	19.33	19	12.67
Total	150	100	150	100

In phase II the value or score attributed to each face as a function of the pupil diameter via the VAS was computed and grouped by sex. **Table 2** shows the mean values obtained through the VAS according to sex and pupil diameter (2, 3, 4, 5 and 6 mm). The mean value for the men's attribution of attractiveness was higher for faces with a 5 mm pupil diameter (M = 4.12), followed by faces with a 4 mm diameter (M = 4.02). The mean value for the women's attribution of attractiveness was higher for faces with a 5 mm pupil diameter (M = 3.77), also followed by the 4 mm pupil diameter (M = 3.45). The mean value for the men's (M = 2.73) and the women's (M = 2.33) attribution of attractiveness was lower for faces with a 2 mm pupil diameter. The statistical analysis (two-way analysis of variance [ANOVA]) indicated no differences between the male and female group factor ($p > 0.05$) and no interaction of the groups in relation to the pupil diameter ($p > 0.05$). The analysis indicated significant differences only in relation to the pupil factor [$F(1, 234) = 19.06$, $p < 0.05$]. The post-hoc Tukey HSD test showed that both men and women differently judged the faces with a pupil diameter of 2 mm in relation to the faces with pupil diameters of 3, 4, 5, and 6 mm ($p < 0.05$) and the faces with a pupil diameter of 5 mm in relation to the faces with a pupil diameter of 3 mm ($p < 0.05$). These results indicate that the faces with a 5 mm pupil diameter received the highest scores (i.e., they were judged as being more attractive) whereas the faces with a 2 mm pupil diameter received the lowest scores (i.e., they were judged as being less attractive) from both the men and the women.

TABLE 2
Means and standard deviations of the scores related to the attribution, by men and women, of the degree of attractiveness for neutral faces with different pupil diameters using the visual analogue scale (Experiment II)

	Men		*Women*	
Diameter	*M*	*SD*	*M*	*SD*
2 mm	2.73	1.54	2.33	1.48
3 mm	3.57	1.73	3.15	1.57
4 mm	4.02	1.71	3.45	1.51
5 mm	4.12	1.75	3.77	1.75
6 mm	3.58	1.59	3.20	1.68

Figure 2 shows a similar pattern in the shape of the attractiveness curve between men and women, thus indicating that, in phase II, the men and the women behaved similarly in relation to the judgment of the attractiveness of the faces with varying pupil sizes, even though the men assigned attractiveness values that were slightly higher for all pupil diameters in comparison with the women.

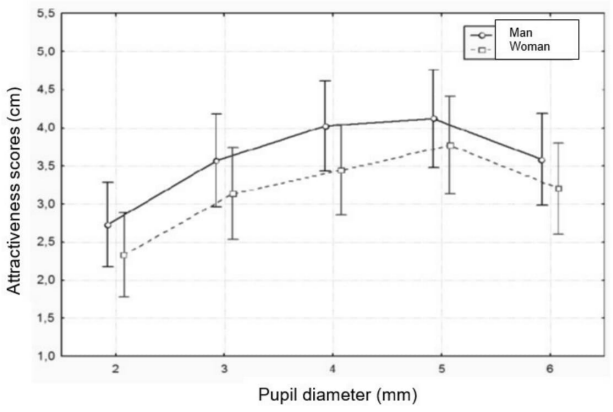

Figure 2. Relationship between the values related to the attribution, by men and women, of the degree of attractiveness for neutral unfamiliar faces with pupil diameters of 2, 3, 4, 5, and 6 mm, in accordance with the visual analogue scale (Experiment 2).

In general, it can be concluded that the results of phases I and II show a relationship between the variation in the pupil diameter of neutral unfamiliar male and female faces and the attribution of facial attractiveness, thus demonstrating that the pupil diameter has an important role in the phenomenon of facial attractiveness.

Discussion

Through two behavioral experiments (Phases I and II) employing different methodologies, this study aimed to test the hypothesis that there is an interaction between the pupil diameter (2, 3, 4, 5, and 6 mm)of unfamiliar neutral faces of men and women and the facial attractiveness judged by young heterosexual adults of the opposite sex. Our results show that the judgment of attractiveness by men and women varies according to pupil diameter, thus confirming the hypothesis that was tested in the two phases, but men and women behave similarly to pupil diameter variation where both have an inverted U-shaped attractiveness curve with greater attractiveness to medium-sized pupils (Caryl et al, 2009).

The results of Phase I (see **Table 1**) showed that the least frequent response occurred for the 2 mm pupil diameter for both the men (9.33%) and the women (8%). The results showed that the most frequent responses – 76% for the men and 76.7% for the women – were attributed to the 4, 5, and 6 mm pupil sizes, though with a variation in the concentration of the most frequent response for the men and the women because the neutral face with the 5 mm pupil diameter was considered to be the most attractive by the men

(30.66%) whereas the neutral face with the 4 mm pupil diameter was considered to be the most attractive by the women (38.67%) (**Table 1**).

The results from phase II showed that in the VAS, the neutral faces with the 2 mm pupil diameter received the lowest mean scores in the attribution of attractiveness by the men (M = 2.73) and the women (M = 2.33) whereas the highest mean scores in the attribution of attractiveness occurred for the neutral faces with a 5 mm pupil diameter for the men (M = 4.12) and for the women (M = 3.77).

The results of phases I and II showed that the manipulation of the pupil diameter in neutral male and female faces has an important role in the judgment of facial attractiveness, in accordance with what was expected, given that neutral faces with larger pupil diameters (4 and 5 mm) were attributed higher attractiveness scores. In a certain way, these results corroborate the pioneering studies that reported the existence of a relationship between pupil diameter and attractiveness related to of neutral face visual stimuli (Hess & Polt, 1960; Hess, 1965). However, it is important to note that our experiments and the experiments of Hess were conducted with different methods and objectives.

These results showed differences in the judgment or attribution of the attractiveness response. This study suggests that possible changes in attractiveness may be related to physiological and neurochemical changes that work for an adaptation of the pupillary diameter through the light reflex (Caryl et al., 2009; Tombs & Silverman, 2004). Investigations such as these should be made with other non-invasive behavioral and technical methods, such as functional magnetic resonance imaging, to investigate whether there is a difference in the cortical regions of the nervous system in men and women related to the attractiveness response of the opposite sex, highlighting decision-measures of sexual arousal. Hess (1965) reported that, when presented to the opposite sex, photographs of naked men and women produced greater dilation of the pupil; however, no differences in sex-related judgment were reported. Hess (1965) reported that, when presented to the opposite sex, photographs of naked men and women produced greater dilation of the pupil; however, the authors did not state which factors are associated with dilation of the pupil.

It is important also to investigate studies with spatial resolution through event-related fMRI technique in the judgment of attractiveness by men and women. The fMRI technique could be related to the intensity of activation of the amygdala and the pre-frontal cortex lateral dorsum, this scheme can present the activation of the cortical mechanisms of the cogitative and emotional processes. Some event-related fMRI studies report that the amygdala is involved in detecting changes in pupil size (Amemiya & Ohtomo, 2012; Demos et al., 2008), exerting an index of arousal and/or interest, even in the absence of explicit knowledge of the pupil manipulation. According to Demos et al., the larger the pupil diameter of the female faces is, the greater the functional activity of the amygdala in the men. Amemiya and Ohtimo find that the amygdala is activated more for faces with large pupils, regardless of the sex. The findings of our study may reinforce the importance of the functional magnetic resonance technique to investigate whether the functional activity of the amygdala-related difference in response of women and men has sex for different pupil diameters. It is also possible that the neurophysiological mechanisms involved in the release of noradrenaline to activate the iris muscles responsible for varying the pupil diameter are related to different attractiveness between men and women (Demos et al., 2008; Stark & Kwak, 2013).

In general, our results support the idea that pupil diameter plays an active role in the attribution of facial attractiveness, regardless of sex, and that men and women may respond in a similar way to the variation of the pupil diameter in neutral faces of the opposite sex.

Our results are also in accordance with analytical processing because variation in pupil size is a signal to check the patterns of a visual stimulus. The analytical process is considered to be distributed and specialized, and it is initially destined for analyzing the specific attributes of a given stimulus, unlike that advocated by global processing (Gazzaniga et al., 2006). Thus, the processing of individual traits may be described as a source for analytical processing (Campbell et al., 2001).

Final considerations

Our results reinforce the importance of behavioral studies that discuss that the diameter of the pupil plays an important role in the attribution of facial attractiveness. New studies are important for investigating the effects of pupil diameter in faces with emotional expressions with positive and negative valence (Geangu, Hauf, Bhardwaj, & Bentz, 2011) and attentional mechanisms (Bombeke et al., 2015). Another proposal would be to evaluate effects of attractiveness in children, individuals with neuropsychiatric disorders, and homosexual individuals, especially in relation to increasing the social connectedness between individuals, as suggested by Graur and Siegle (2013).

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