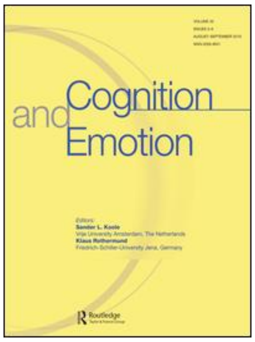



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BRIEF ARTICLE



# The role of pupil size in communication. Is there room for learning?

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**ABSTRACT**

The eyes are extremely important for communication. The muscles around the eyes express emotional states and the size of the pupil signals whether a person is aroused and alert or bored and fatigued. Pupil size is an overlooked social signal, yet is readily picked up by observers. Observers mirror their own pupil sizes in response, which can influence social impressions. In a landmark study by Hess [1975. The role of pupil size in communication. *Scientific American*, *233*(5), 110–119] it was shown that individuals with large pupils are perceived more positively than individuals with small pupils. In that behavioral study, participants were asked to draw pupils in line drawings of faces with empty irises and they drew large pupils in the happy face, and small ones in the angry face. The current study tested 579 participants (aged 4–80 years old) and extended this work by showing that this association between large (small) pupils and a positive (negative) impression develops over age and is absent in children. Several explanations for how individuals through interactions with close others learn that large pupils mean care, interest and attention and small pupils the opposite, are discussed. To conclude, this study shows that pupil size and emotion perception are intertwined but that their relationship develops over age.

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Inferring anothers' internal state of mind from reading his or her intended or unintended bodily signals is a key aspect of social cognition and forms the basis of a healthy social life. During social interactions probably the first thing we notice, is whether the other person is paying attention to us or not. Registering this is so fundamental that this skill is present from birth (Farroni, Csibra, Simion, & Johnson, 2002). When we notice that someone is paying attention and looking at us, another signal that is unconsciously perceived is the pupil size of that person (Harrison, Gray, & Critchley, 2009). Changes in pupil size are regulated by the autonomic nervous system and are beyond our control, yet reflect ongoing cognitive effort, social interest and attention, surprise or uncertainty, as well as arousal paired with a range of emotions (Bradshaw, 1967; Hess, 1975; Lavín, San Martín, & Jubal, 2013). Precisely because pupil changes are unconscious, they provide a veridical reflection of a person's inner state and thus may be a particularly relevant source of information for observers (Kret, 2015).

In an early study, Hess (1965) investigated that idea by presenting a group of men a series of pictures of which two showed an attractive young woman. One of them had been retouched to make the woman's pupils larger and the other to make them very small. Despite being unaware of the manipulation, participants liked the woman with the large pupils better, describing her as "more feminine", "prettier" and "softer" than the women with small pupils (Hess, 1965). However, whether this positive social impression from large pupils is innate like the human smile (which is universally interpreted as positive, i.e. Ekman, 1983), or is based on learned associations, is a question that has up to now not been answered.

There are two possibilities. First, it is possible that the positive evaluation of an individual with large pupils is something that is learned through experience

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and exposure, by means of trial and error. The mechanism might be similar to the one underlying the own-race bias, where people affiliate more with similar others, i.e. their ingroup, and less with people that are more different, because they have had less exposure to those people and as a consequence, less positive experiences as well (for a review, see Pettigrew, Tropp, Wagner, & Christ, 2011). In a similar way, people may be conditioned and have come to associate interaction partners with large pupils as trustworthy (Kret & de Dreu, 2017; Kret, Fischer, & De Dreu, 2015), caring and attentive (Kang & Wheatley, 2017) because of positive experiences with these partners. Second and alternatively, this positive association between looking into the eyes of someone with large pupils and liking or trusting that person better, is a skill that is present from birth, much like our tendency to attend to eyes, especially when these eyes look at us (Farroni et al., 2002).

The present study aims to get insight into the question of whether the positive evaluation of someone with large pupils is innate or prone to changes over age. To that extent, I adapted a very simple paradigm from Hess (1975) where he showed adult participants two line drawings of a face of a happy and an angry person. The eyes of these line drawings did not contain pupils and participants were asked to draw these in. What was observed was that participants drew large pupils in the happy face and small pupils in the angry face. The aim of the current study is threefold. A first aim of this study is to replicate this earlier finding. A second aim is to investigate potential alterations over age. A third aim is to explore gender differences. While Hess (1975) did observe sex differences in the perception of pupil size, Kret and de Dreu (2017) did not. Thus, whether this putative difference in drawn pupil size in the happy compared to angry faces is modulated by gender is an open question. In the current study, a large number of subjects with a wide age range was asked to draw pupil sizes in the line drawings first used in the study by Hess (1975).

## Method

### Participants

In total, 579 participants (357 female) with a mean age of 22.18 (range 4–80 years old) drew pupils in a line drawing of a happy and an angry face. Data of 443 participants (267 female) were collected in the Science museum NEMO during two holiday weeks in 2015. There was no stopping-criterion and all museum visitors could participate if they wanted. Participants were approached by the test-leaders, attracted via posters that hung in the museum or were informed via a call on the museums' "Science Live"-website. The age of participants was not normally distributed and peaked around the ages 6–8 and around the age of 40. In order to fill the twenties-gap, 136 students (90 females) were recruited from the University of Amsterdam. Their mean age was 21.88 years old (range 18–39 years old). See Figure 1(A) for the final age distribution. Five participants were excluded because they drew abnormal pupils (for example two pupils per eye or star-shaped pupils). All participants filled out an informed consent before taking part in the experiments. For children, parents signed the informed consent. The study was performed in accordance with the Declaration of Helsinki and approved by the local medical ethical committee.

### Stimuli

Two line-drawings of a happy and an angry face were taken from Hess (1965) and printed out. See Figure 1(B).

### Procedure

Participants were told that the pupils were missing in the printed drawing and asked to draw them and to really color them in. The order at which the drawings were handed out was randomized. After data collection, all line drawings were scanned and imported into Adobe Photoshop. Next, the number of pixels that fell within the outline of the drawn pupils were counted and served as the dependent variable.

### Statistical analysis

Data were analyzed in a two-level Generalised Mixed Model, implemented in SPSS version 20. The two drawings were nested within participants. As the drawn pupil sizes were significantly skewed to the right, a gamma regression was selected (similar to log-transforming the data). "Emotion" (angry and happy) was included as a fixed factor and the intercept as a random factor.

## Results

As predicted, a main effect of emotion was observed. Participants drew larger pupils in the happy face than in the angry face $F(1, 1{,}141) = 13.302$, $p < .001$. However, when adding Age and Sex of Participant

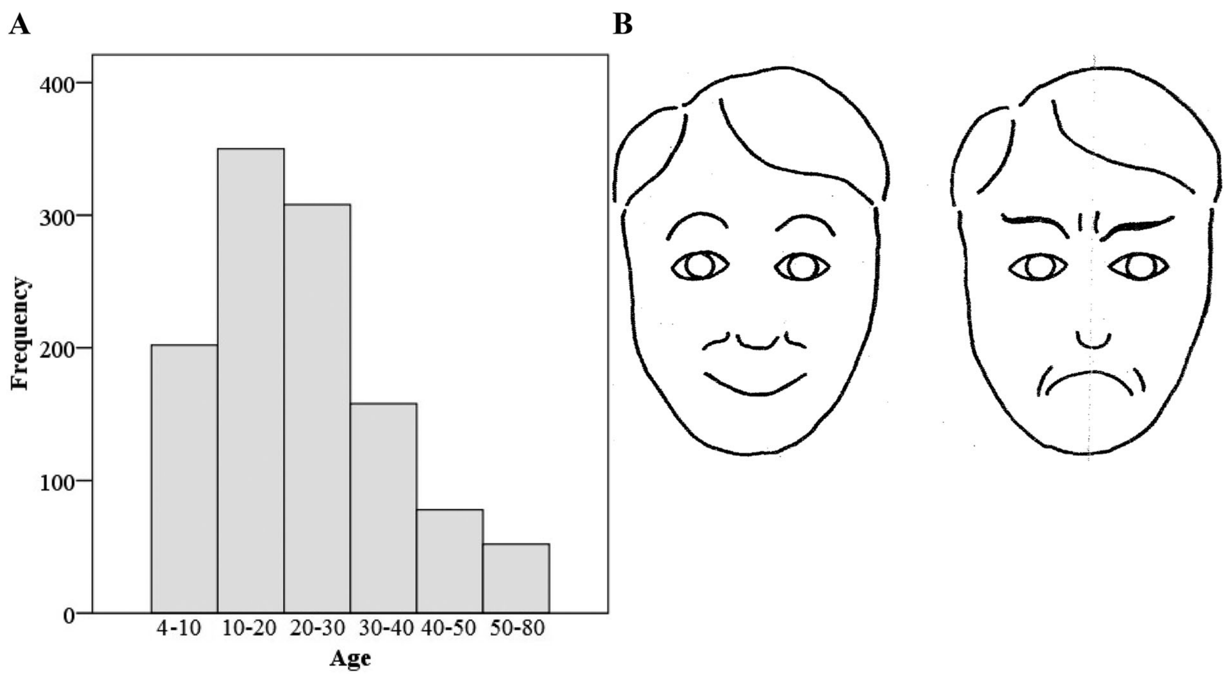


**Figure 1.** Methods of the study. (A) Frequency graph of the participant sample, divided in age blocks (for visualisation purposes only). (B) The drawings that were used in the study (adapted from Hess, 1975).

and their interactions with Emotion to the model, the main effect of Emotion disappeared ($p = .301$). In order to get to the best fitting, yet most parsimonious model, non-significant factors were dropped one by one, starting with the three-way interaction, then the two two-way interactions with Sex of Participant and the final factor that was dropped was Sex of Participant. With the final model, a significant interaction effect was observed between Emotion and Age of Participant[1] $F(1,1,131) = 12.464$, $p < .001$, showing that the difference in the size of the pupils drawn in the happy face as compared to those drawn in the angry face, increased with age. When investigating the effect of Age of Participant separately per Emotion Category, this effect turned out to be driven by the angry faces $F(1, 565) = 14.926$, $p < .001$ (happy: $p = .451$). Thus, over age, participants started to draw the pupil sizes in the angry face smaller (Figure 2). There was no main effect of Emotion ($p = .281$) and no main effect of Age ($p = .203$).

## Discussion

"When we say that someone's eyes are soft, hard, beady, cold or warm, we are in most instances referring only to a certain aspect of that person's eyes: the size of the pupils" (Hess, 1975). Large pupils are generally perceived positively and small pupils negatively (see also, Amemiya & Ohtomo, 2012; Demos, Kelley, Ryan, Davis, & Whalen, 2008; Harrison, Singer, Rotshtein, Dolan, & Critchley, 2006; Harrison, Wilson, & Critchley, 2007). Taking a developmental perspective, the findings of the current study suggest that these associations are most likely learned rather than hard-wired. In this study, participants from different ages were asked to draw pupils in two line drawings of a happy and an angry face. Overall, participants drew larger pupils in the happy compared to the angry face, and this study therewith replicates Hess (1975) earlier description of this phenomenon. Interestingly though, the current study shows that this difference in pupil size drawn in the happy versus angry face continues to increase throughout people's lifetime and is absent in young children, independent of the gender of the participant.

In the next section, I will discuss the possible mechanisms that might explain these effects. First, I will discuss how these associations between "large pupils" and "a positive state" and "small pupils" and "a negative state" may be formed. Second, I will try to provide an answer to the question of why these associations continue to strengthen over age and even over old age. Third, I will discuss the finding that the age-related changes in pupil perception were mostly driven by the smaller drawn pupils in the angry faces.

In line with previous research, the current study shows that large pupils are overall perceived more positively and small pupils more negatively (Amemiya & Ohtomo, 2012; Demos et al., 2008; Harrison et al., 2006). Possibly, because large pupils fit in the baby schema (children tend to have larger pupils than adults, as have the good characters in cartoons), people associate large pupils with harmlessness. However, research has shown that children are as sensitive to the baby schema as adults, and like faces that fit into that scheme much better than ones that do not (Borgi, Cogliati-Dezza, Brelsford, Meints, & Cirulli, 2014). Thus, that large pupils are consistent with the baby scheme is at least not the full explanation for why large pupils are liked so much. An alternative explanation is that people in positive compared to negative states do have actual large c.q. small pupil sizes. Pupil size is governed by both sympathetic and parasympathetic inputs. Pupil dilation is typically seen in tasks requiring either physical (lifting weights) or mental effort, including tasks with a high working memory load (Kahneman & Beatty, 1966). Moreover, emotional arousal, regardless of valence, is also reflected in the magnitude of pupillary dilation (Bradley, Miccoli, Escrig, & Lang, 2008; Hess & Polt, 1960; Kret, Roelofs, Stekelenburg, & de Gelder, 2013; Kret, Stekelenburg, Roelofs, & de Gelder, 2013) and is associated with sympathetic activity and norepinephrine levels, elicited by the locus coeruleus (Joshi, Li, Kalwani, & Gold, 2016). Yet, initial pupillary dilations and those driven from higher order visual features are largely driven by release of parasympathetic inhibition at the Edinger-Westphal nucleus (Barbur, 2004). Pupillary constriction occurs to stimulus attributes such as the onset of colour change, spatial structure or coherent movement (Barbur, 2004) but a general small pupil size can be indicative of fatigue as well (Morad, Lemberg, Yofe, & Dagan, 2009). Thus, on the basis of people's pupil size alone, it is hard to say anything meaningful about their state of mind and whether that is positive or negative. However, with extra contextual information, I would like to argue, it may be possible. In the context of a social interaction for instance, pupillary cues might be particularly meaningful.

Previous research suggests that pupil size does play a role during social interactions. For example, two

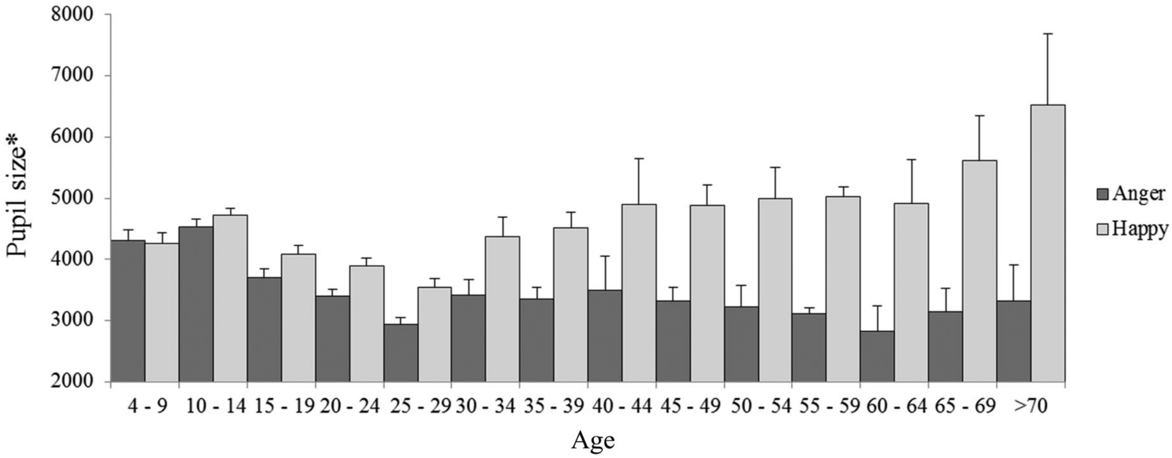


**Figure 2.** * Number of pixels falling within the pupil as counted by using Photoshop. The labels "happy" and "anger" refer to the facial expression of the face participants were instructed to draw the pupils in with pen. Over age people differentiated more between the two emotion categories. Error bars represent the standard error of the mean. Whereas the data is here presented in blocks of age, age was treated as a continuous variable in the analysis.

studies have shown that the association between large pupils and a perceived positive state of the observed is strengthened when the pupils of the observer mirrored those of the observed (Kret et al., 2015; Kret & de Dreu, 2017). The reverse, a less positive impression of an observed partner with constricting pupils when these pupils were mimicked, was observed in one of the two studies (Kret & de Dreu, 2017). One possibility is that the pupils of the observer and their associated neural correlates provide direct or indirect feedback to higher order mentalizing and/or social decision making areas in the brain (Bullucci, Chernyak, Goodyear, Eickhoff, & Krueger, 2017). Possibly, large own pupils then signal a positive interaction, the other is aroused and interested, and stimulate prosocial behaviors including decisions of trust. Small own pupils signal that the other is tired, sad or bored with the interaction, and stimulate withdrawal. There is indeed some evidence that the Edinger-Westphal nucleus is involved in pupil mimicry (Harrison et al., 2006), suggesting that a parasympathetic mechanism might be at play that mediates cortical influences on pupil size. Indeed, in another study, it was shown that when observed and observer's pupil size did not match, this yielded activity in the anterior insula, amygdala and anterior cingulate, suggesting that people are continually appraising "mismatched" changes in observed and observer's pupil size, potentially heralding a shift in the observed individual's social or motivational state (Harrison et al., 2009). The effect of age that was observed in this study, suggests that this appraisal mechanism continues to develop throughout our life.

From the developmental literature it is known that activity patterns in the mentalizing network in relation to social approach are still developing up into adulthood (Fett, Gromann, Giampietro, Shergill, & Krabbendam, 2014, for reviews, see Guyer, Silk, & Nelson, 2016; Prochazkova & Kret, in press). Pupil mimicry, on the other hand, is already fully present in 6-month old infants (Fawcett, Wesevich, & Gredebäck, 2016). Possibly then, pupil mimicry is inborn and by mimicking close others, others that pay attention to us (parents, siblings), we pick up these pupillary changes and learn that large, dilated pupils are associated with love, care and attention and that small pupils signal the opposite. If so, pupil dilation mimicry is positively reinforced and develops as the default (Kret et al., 2015; Kret & de Dreu, 2017). Still, this explanation is not fully satisfying as the difference between the drawn angry and happy pupils manifests itself most clearly from the age of 30 and continues to increase up to old age. Could parenthood perhaps be a possible explanation? Unfortunately, participants in this study were not asked whether they had children or not, but the adults visiting the science museum most often came there with their children. Parenthood might be of influence, as in an earlier study that tested pupil mimicry in chimpanzees, pupil mimicry was strongest in the three chimpanzee mothers that were included in our sample (Kret, Tomonaga, & Matsuzawa, 2014). It is possible that parents are more sensitive to emotional cues of others as during interactions with pre-verbal children they have learned to pay attention to them. This would be an interesting avenue for future research.

The current study also shows that the age-related changes in pupil perception were mostly driven by the smaller drawn pupils in the angry faces by the older participants. Although a numerically consistent opposite trend was observed for the happy faces, this did not reach statistical significance. This result was not hypothesised a priori but I will here discuss this finding in the context of what is known about effects of age on processing emotion signals. Previous research has shown that relative to their younger counterparts, older people attend to and remember more positive than negative information (Mather & Carstensen, 2005). For instance, compared to younger adults, older adults direct their gaze toward faces with positive expressions and away from negative faces (Isaacowitz, Allard, Murphy, & Schlangel, 2009a; Isaacowitz, Toner, & Neupert, 2009b; Mather & Carstensen, 2003) This effect is not related to cognitive or neurological decline, but is instead supported by a top-down, motivational explanation (Mather & Carstensen, 2005). From the literature on what is called "the positivity bias", one would expect that in the current study, older people would pay particularly more attention to the pupils that were missing in the happy face and draw very large ones to fill the empty eyes with. But instead, the results of the current study show that the age effect was driven by the angry faces, which they gave tiny pupils. As already mentioned above, it is possible that subjects' own pupil sizes impacted on how the pupils were drawn in the line drawings and differently so, depending on their age. Importantly, it is well known that young children generally have larger pupils than adults and also that older adults have smaller pupil sizes than younger adults (Bitsios, Prettyman, & Szabadi, 1996). In addition, research has shown that the pupil dilates in response to emotional faces (Bradley et al., 2008; Kret, Roelofs, et al., 2013; Kret, Stekelenburg, et al., 2013) but that this response declines over age (Allard, Wadlinger, & Isaacowitz, 2009). It is possible therefore that people drew pupil sizes that were in accordance with their own pupil sizes: old people with relative small pupils and small pupil responses following emotional faces, drew consistently small pupils in the angry faces. Perhaps their positivity bias helped to overcome that effect when being confronted with happy faces. This is an admittedly speculative interpretation, but it provides one avenue for future studies to look into.

To conclude, this study shows that people associate positive faces with large pupil sizes and negative faces with small pupil sizes. This effect increased over age, which was especially related to older individuals drawing particularly smaller pupil sizes in the angry face than younger individuals. The fact that age is of influence here at all, makes it most likely that real world experiences are necessary to establish these associations.

## Note

1. This effect is still significant when excluding children younger than nine years old who may not yet possess the fine motor skills needed to draw the pupils $F(1, 999) = 12.003$, $p < .001$. Please note however, that only the very young children were not as proficient in drawing perfect circles as the older ones. Still, even 10-year olds with good drawing skills did not draw larger pupils in the happy compared to angry face.

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