PSIHOLOGIJA, 2014, Vol. 47(3), 287–301 UDC 159.937.5.07:75.01

DOI: 10.2298/PSI1403287H

The Mona Lisa effect: Testing the limits of perceptual robustness vis-à-vis slanted images

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We report three experiments that test the limits of the Mona Lisa effect. The gaze of a portrait that is looking at us appears to follow us around as we move with respect to the picture. Even if our position is shifted considerably to the side, or if the picture is severely slanted, do we feel the gaze to be directed at us? We determined the threshold where this effect breaks down to be maximally 70° of picture slant relative to the observer. Different factors modulate this remarkable robustness, among them being the display medium and the nature of the picture. The threshold was considerably lower when the picture was mounted on a physical surface as opposed to a computer simulation of slant. Also, the more the portrayed object deviated from the photograph of a human head, the less robust the Mona Lisa effect became. Implications for theories of perspective distortion are discussed.

The eyes of a portrait appear to follow the observer as he or she views the image from different angles. This effect is often called the *Mona Lisa effect* (see e.g., Maruyama, Endo, & Sakurai,1985; Rogers, Lunsford, Strother, & Kubovy, 2003), although this "eye following" effect has been noted much earlier as for instance by William Wollaston, who noted that not just the eyes but also the nose appear to follow the observer (1824, p. 255). The Mona Lisa effect appears to hold even for large picture and/or observer displacements and the effect is similar for objects other than human faces (Goldstein, 1987; Kerzel & Hecht, 1997). In the current study we investigated the limits of this effect. When does the Mona Lisa effect break down once observer displacement (or slant of the picture) becomes ever more extreme?

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Acknowledgements. We thank Agnes Münch for programming the interactive displays and Hannah Gamerdinger and Malte Klüver for their help with stimulus construction and data collection. Dejan Todorović provided valuable comments on an earlier version. The first author was supported by a joint grant of the Deutscher Akademischer Austausch Dienst and the Japanese Society for the Promotion of Science.

We also explored whether the robust unchanged pointing direction of pictorial objects with respect to a displaced observer breaks down at a similar point in portraits of human faces (Mona Lisa effect), other face-like stimuli, and plain objects. Note that the break-down point of gaze direction or object orientation vis-à-vis slanted images describes a robustness of the Mona Lisa effect that is different from Kubovy's (1986) notion of "*robustness of perspective"*, which he used to describe the observer's tolerance for distortions as seen from the painter's point of view. We use 'robustness' with respect to the observer's point of view. Thus, by robustness we mean the preservation of the perceived spatial layout of the picture as we change our vantage point to a different position in front of the picture. In a sense our notion of robustness is egocentric whereas Kubovy's and Halloran's (1989) notion of perspective robustness is allocentric[1].

Some rather strong picture slants have been used as stimuli for gaze direction perception, whereby we know that the Mona Lisa effect is maintained up to 45º, but to our knowledge the limiting case has not yet been determined. The observers who participated in the experiment of Maruyama, Endo, & Sakurai (1985) judged the apparent gaze direction of a photographed face. The photo was placed on a board initially in the observer's frontoparallel plane. The board could be slanted by 45º clockwise around its vertical axis. The face orientation and gaze direction of the photographic face was equivalent to that of the "Mona Lisa" in Leonardo da Vinci's original painting (1503 – 1505). Six of twelve observers in the frontoparallel plane condition and seven of twelve participants in the 45º slant condition reported that the gaze was directed at them. In their second experiment, the observers had the same task this time with the portrait photograph of a female model. In this case eleven of twelve participants estimated the apparent gaze as being directed toward them in the 45º slant condition.

In an experiment by Rogers, Lunsford, Strother, and Kubovy (2003) observers judged gaze direction of photographs presented on a computer monitor, which was rotated by 0º, 15º, 30º, and 45º about its vertical axis. If the photographed model was looking straight ahead toward the station point of the camera, the portrait appeared to be looking at the observer when the picture was slanted. Thus, the Mona Lisa effect proved stable for slants of up to 45º in the horizontal plane. In a more subtle investigation, Todorović (2009) found that at slants of 30º slight changes in the perceived gaze direction can be demonstrated when using very simple sketches of faces.

In our own experiments (Boyarskaya & Hecht, 2012) we confirmed the Mona Lisa effect to be a general phenomenon that generalizes to picture and observer displacements in the horizontal, vertical, and diagonal. We presented a maximal viewing angle of 30º when picture and observer were shifted in opponent directions. All observers appeared to perceive the portrait's straight ahead gaze as looking directly at them, no matter what vantage point or picture position was assumed.

1 We are grateful to Dejan Todorović for pointing out this difference in the use of robustness.

The current study sought to address the following questions:

(1) Is the Mona Lisa effect maintained robustly for more extreme slants exceeding 30º and 45º, which cause even stronger perspective transformations, and if not, at which slant will the Mona Lisa effect break down? In theory, Mona Lisa could maintain her gaze until the eyes are no longer recognizable. However, when observing the powerful effects of anamorphic art (e. g. “The Ambassodors” by Hans Holbein, 1533), such breakdown is likely to occur before the picture is slanted all the way toward the edge-wise view.

(2) How important are visual cues provided by the picture surface itself? Such cues about slant cannot be entirely eliminated when dealing with a physical picture, however, they can be eliminated when slant is merely simulated.

(3) Do the richness of visual cues and the naturalistic rendering (in this case the similarity to a real human face) affect the gaze perception of the picture? To vary naturalness, we used a photograph of the real human face, a cartoon-drawing and a very simple smiley-sketch.

One explanation of the effect has been proposed under the label of *compensation theory*. It explains the Mona Lisa effect by way of an unconscious psychological process of compensation if the viewer’s vantage point differs from the original compositional viewpoint (Pirenne, 1970). That is, from different viewing positions the observer recreates the picture according to the supposed center of projection. In some sense compensation can be thought of as a as disembodied eye looking at the painting from an unchanged vantage point. Such compensation might be facilitated if the image surface is visible and even more so if the frame is also visible. In the latter case, the compensation would not be based on pictorial but rather on object cues.

Thus, the visibility of the picture surface plays a decisive role in this robustness as it makes the information about the picture plane, which is required to compute the amount of compensation, more salient. Such a prediction would for instance be made by Hanada (2005) who found that the picture surface is used to determine picture slant and possibly to correct for it. It would also be compatible with Vishwanath, Girshick, and Banks (2005) who suggest that local surface orientation estimates are indeed being made by the visual system.

Some experiments which support compensation theory, found that pictorial layout of slanted pictures appeared to be undistorted when the picture surface was visible (e.g., Rosinski, Mulholland, Degelman, & Farber, 1980). Others have raised criticism against the very notion of compensation (e. g. Busey, Brady, & Cutting, 1990). Yang and Kubovy (1999) expanded the compensation hypothesis into a *modified compensation theory*. According to it, compensation is not an “all-or-none” mechanism, it depends on the degree of visibility of the picture surface slant. The more visible the picture surface, the less distorted (compared to what projective geometry would predict) observers perceive pictorial space to be.Other competing theories have been entertained to explain robustness (indiscrimination, array-specificity, iris/head account). They have been laid out in detail elsewhere (e.g., Todorović, 2006, 2009). In his iris/head account, Todorović suggests that slant of the picture produces differential perspective foreshortening of the nearer and farther portions of the face and thus alters the cues of head orientation. This account nicely explains slight changes in perceived gaze direction within the realm of mutual gaze. Note that the range of gaze directions considered to constitute being looked at is rather large, about 10º under normal circumstances (Gamer & Hecht, 2007).

None of the current theories makes explicit predictions about the point where the Mona Lisa effect breaks down phenomenally. They need to be incorporated into the respective theories. Compensation theory would predict that additional cues about the slant of the picture surface should increase robustness by way of facilitating compensation. Thus, it predicts better tolerance for real as compared to computer simulated pictures. The iris/head account, in contrast, would predict that extraneous cues specifying the picture slant do not matter as long as the eccentricity cues within the face remain recognizable.

(4) Finally, we examined whether expectations about the picture's orientation might exert an *anchoring effect*. The initial orientation of the picture could serve as a reference point and introduce a bias. Thus, we used two initial orientations for picture presentation: frontal view (eye-contact with the portrait possible) and side view (no eye-contact possible). From the initial frontal orientation, observers rotated the picture away from themselves until they did not perceive eye-contact anymore. In the case of an initial side view, they rotated the picture toward their line of sight until they started to perceive eye-contact. If anchoring was the case, the estimated slant would depend on the initial "anchor" and produce a hysteresis effect. As the picture is slanted, the impression of eye-contact would continue longer in the case of initial frontal perspective and would start later in the case of an initial condition without eye-contact.

Experiment 1: Natural and schematic faces

Although the Mona Lisa effect seems to imply that the robustness toward picture slant or observer displacement is limited to faces, this is not so. Goldstein (1979; see also Goldstein, 1987 Exp. 3) has already used both photographs of faces and arrangements of dowels as stimuli. Both showed a similar if differential effect and picture slants up to 70º were tolerated. Goldstein, however, did not ask his subjects to judge whether the person of the picture appeared to look at the subject. We decided to directly assess the phenomenal experience of being looked at (or pointed at). We used a computer-simulation of picture slant to start with and used faces differing in naturalness (degree of similarity to a human face), and then introduced rectangular objects in Experiment 2. We also varied the presence of a frame indicative of the degree of slant. Finally, in Experiment 3 we attached photographs of the faces to a turntable and had subjects physically turn the pictures.

Methods

Participants. 19 volunteers (13 female and 6 male) were recruited for this study. Their average age was 24 (*SD* = 8.04) years. All participants had normal or corrected to normal vision and were naïve about the purpose of the experiment. They gave informed consent, and the experiment was conducted in accordance with the Helsinki Declaration.

Stimuli, design and equipment. We presented three kinds of pictures on a computer monitor: a photograph of a female face, a female cartoon drawing, and a smiley sketch. For the portrait photograph, we asked a model actress to direct her gaze at the camera (gaze angle of 0°, straight ahead). The lens was positioned 50 cm in front of the model at eye-level. Then a cartoon drawing and a smiley were produced and scaled such that the height of the eyes was equivalent in all pictures. The pictures were presented either on a white background, or on a grey background which was suggestive of a frame (see Figure 1). The picture size was 11.3 x 14.9 cm, occupying two thirds of the grey frame when in frontal view.

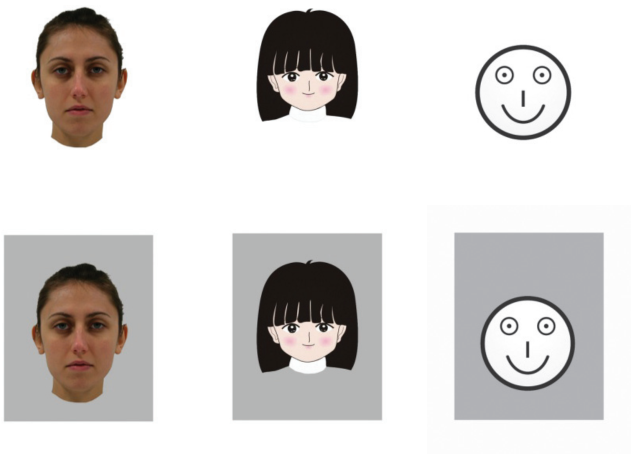

Figure 1. Pictures (frontal view) used in Experiment 1: a photograph, a cartoon drawing, and a smiley sketch. *Top panel:* pictures on white background; *bottom panel:* pictures on grey background, here referred to as frame. (Online in color.)

The picture appeared either in frontal view (perpendicular to the observer's line of sight) or rotated by 90° about its vertical or horizontal axis (side view) such that at the beginning of the trial only a thin line was visible. The task was to rotate the picture out of (or into) the monitor's picture plane using the arrow keys on a keypad. The slant of the picture should be set to the angle where it was on the verge of stopping to gaze at the observer (for initial frontal views), or where it was on the verge of starting to make eye-contact (for initial side views).

Thus, we had the following factors: **rotation direction (4)** (clockwise and counter-clockwise yaw for vertical axis rotations; pitch upwards and downwards for horizontal axis rotations) crossed with **initial orientations (2)** (frontoparallel, on edge). As the starting point always corresponded to an extreme setting, in each condition only one rotation direction was possible. Observers were of course allowed to go back and forth until they had found the desired degree of slant. The rotation directions (see Fig. 2) and initial orientations were fully crossed with the three kinds of **pictures (3)** and with the presence and absence of the **frame (2)**, thus resulting in 48 trials. The order of picture presentations was randomized individually for each participant. The same 48 randomized trials were presented once more after a short break.

Pictures were presented on an LCD computer monitor (47.5 x 29.7 cm) with a resolution of 1680 x 1050 pixels and refresh rate of 60 frames per second. To accomplish the picture slant, the image was mapped onto an invisible 3D-object using the Python-based software Vizard. Observer settings and reaction times were recorded. The distance from the observer to the computer screen was 45 cm.

Procedure. The stimuli were viewed in a dimly lit room. Participants observed the pictures binocularly. Their head was supported by a chin rest directly in front of the center of the computer screen. To rotate the picture, observers used the four arrow keys (up, down, right, and left) on the keypad. Once the picture was presented, an arrow appeared which indicated the rotation direction (see Fig. 2). The arrow was removed after 3 seconds. Corrections were allowed. Every final setting was confirmed with a key-press, which advanced to the next trial. Several practice trials were given to familiarize observers with the task.

Figure 2. Examples of the initial picture presentation. *Left panel:* the picture appeared in the frontal view. The arrow indicates which key to press. The "up"-arrow rotates the head back in pitch about its horizontal axis. *Right panel:* the picture appeared in the vertical side view. By pressing the "left"-arrow the picture rotated clockwise about its vertical axis.

Results and Discussion

We found evidence for the Mona Lisa effect under extreme slant conditions. All pictures (photographed face, cartoon-face and smiley-face) continued to gaze at the observers up to about 70º of simulated rotation with respect to the frontoparallel plane (see Figure 3). A repeated measures ANOVA (3 picture types, 4 picture rotation directions, 2 initial orientations, and presence/absence of frame) was conducted. We found a main effect of picture type: $F(2, 36) = 15.29$, $p < .001$, $\eta^2 = .46$. The Mona Lisa effect broke down significantly later for photographic faces than for cartoon faces and smileys: $F(1, 18) = 21.19$, $p < .001$, $\eta^2 = .54$, and cartoon faces were significantly more robust than the smileys: $F(1, 18) = 10.33$, $p = .005$, $\eta^2 = .36$.

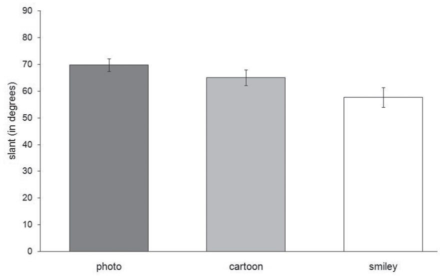

Figure 3. The averaged break-down points for the Mona Lisa effect by picture type. Error bars indicate standard errors of the mean.

To illustrate the findings, pictures of the face and the smiley, both slanted in yaw by 70 degrees clockwise are shown in Figure 4. For a typical observer, at this slant the photograph makes eye contact but the smiley fails to do so.

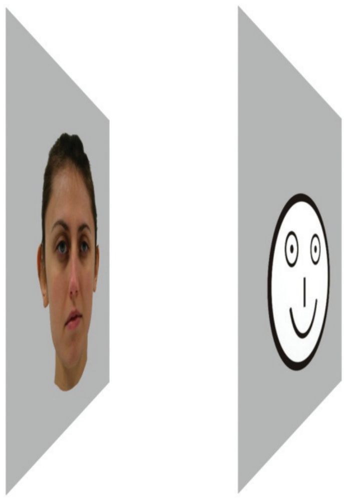

Figure 4: The photograph and the smiley both rotated by 70 degrees counter-clockwise around the vertical axis (yaw). Note that the "frame visible" condition is shown here. (Online in color.)

The direction of picture slant had a significant albeit small effect on the boundary of the Mona Lisa effect. Observers were more tolerant toward slant around a horizontal axis compared to slant around a vertical axis: $F(3, 54) = 4.75$, $p = .005$, $\eta^2 = .21$. When the picture was pitched downwards around its horizontal axis, the subjective eye-contact lasted significantly longer as compared to upwards pitch: $t(18) = 3.13$, $p = .006$. However, there was no difference between clockwise and counter-clockwise yaw rotations: $t(18) = 1.81$, $p = .087$. Figure 5 illustrates the break-down points for the Mona Lisa effect separated by the different rotation directions.

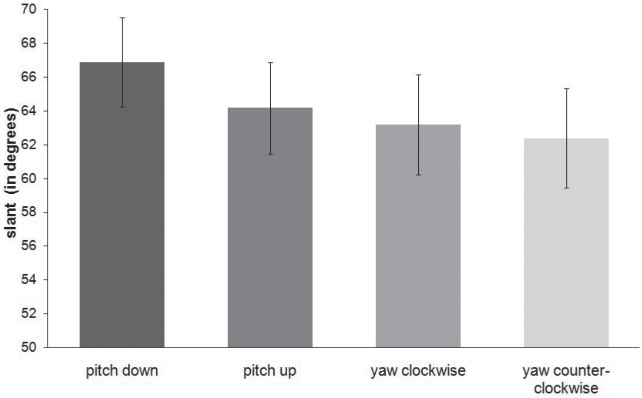

Figure 5. The averaged break-down points for the Mona Lisa effect for all four rotation directions. Error bars indicate standard errors of the mean.

Interestingly, we found an interaction between picture type and rotation direction: $F(6, 108) = 8.23$, $p <.001$, $\eta^2 = .31$. In the case of the smiley-face the difference between the two rotation axes was very pronounced. The photographic face and the cartoon face showed the same tendency but to a much smaller degree than the smileys. Surprisingly, we did not find any significant influence of frame on the break-down point of perceived gaze contact: $F(1, 18) = 1.55$, $p = .229$, $\eta^2 = .08$. However, the pictures with frames have a slight, but consistent tendency to keep the eye-contact longer.

It did not matter whether the initial view was a frontal or a side view. Initial orientation had no effect on the settings: $F(1, 18) = 0.01$, $p = .981$, $\eta^2 <.01$. Thus, it did not matter if the observer rotated the picture away from herself until she did not perceive eye-contact anymore, or if the observer rotated it toward himself until he began to feel the eye-contact. This absence of a hysteresis effect can be interpreted as evidence for the reliability of our results.

Experiment 2: Physical slant

Experiment 1 used simulated slant, which caused the removal of subtle cues regarding the picture surface that could not be simulated. To assess their influence, we replicated experiment using a real-world analog. We placed actual photographs of the face stimuli used in Experiment 1 on a turntable. By slowly turning its base, subjects were able to adjust the physical slant of the picture.

Methods

Participants. 20 volunteers (14 female and 6 male) participated in this experiment. Their average age was 23 (SD = 2.48) years. All participants had normal or corrected to normal vision and were naïve about the purpose of the experiment. They gave informed consent, and the experiment was conducted in accordance with the Helsinki Declaration.

Stimuli, design and equipment. We used the same three kinds of pictures as in the first experiment: a photograph of a female face, a female cartoon drawing, and a smiley sketch. The pictures were initially presented either in frontal view (perpendicular to the observer's line of sight) or rotated by 90° about the vertical axis (side view). If the picture was presented in frontal view, the task for participant was to rotate it until the portrait was slanted to the point of stopping to make eye contact. If the picture was initially presented in side view, participants were asked to rotate it toward themselves until the portrait just started to make eye contact. When the subject was satisfied with the turntable setting the experimenter recorded the slant of the picture as indicated by a pointer on a dial, which was not visible to the subject.

Thus, we had the following factors: **rotation direction (2)** (clockwise and counter-clockwise) crossed with **initial orientation (2)** (frontoparallel, on edge). As the starting point always corresponded to an extreme setting, in each condition only one rotation direction was suggested. Observers were of course allowed to go back and forth until they had found the desired degree of slant. The rotation directions and initial orientations were fully crossed with the three kinds of **pictures (3)**, thus resulting in 12 trials. The order of picture presentations was randomized individually for each participant.

Pictures were presented on a background of hard white cardboard (40 x 38 cm). A transparent envelope at the center of the cardboard served as picture holder. The experimenter replaced pictures by putting them alternately into the envelope. The picture size (11.3 x 14.9 cm) and corresponding visual angles were equal to those in the first experiment. The cardboard wall holding the picture was fixed vertically at the center of the turntable (see Fig. 9). To measure the rotation angle, we used a protractor-like scale underneath the turntable. The scale and the pointer attached to the turntable were invisible to the participants. The pointer consisted of a small metal arrow. The distance from the observer to the picture plane was 45 cm.

Figure 6. Experimental setup used in Exp. 2. (Online in color.)

Procedure. The stimuli were viewed with the right eye through a small aperture. The surrounding laboratory environment was thus hidden from the observer. Only the picture and the cardboard background surface around it remained visible. A chin rest directly in front of the center of the picture supported the observer's head with the portrait's bridge of the nose located exactly in front of the observer's right eye. To rotate the picture, observers rotated the turntable with their hands. Once the picture was presented, the experimenter indicated the desired rotation direction verbally. Corrections were allowed.

Results and Discussion

The Mona Lisa effect broke down for all picture types at the average rotation angle of 38.26°. We did not find any significant effect of picture type ($F(3, 38) = .56$, $p = .573$, $\eta^2 = .02$), or of initial view ($F(1, 19) = .01$, $p = .919$, $\eta^2 < .01$). However, we found an effect of rotation direction: $F(1, 19) = 10.18$, $p = .005$, $\eta^2 = .35$. The Mona Lisa effect was stronger for the rotation clockwise toward the observer / counter-clockwise away from the observer (41.28°, *SD* = 11.87) as compared to the rotation counter-clockwise toward the observer / clockwise away from the observer (35.23°, *SD* = 13.39). This difference may be due to the small divergence in the left and right visual fields of the observer, given that the pictures were observed with the right eye only.

The break-down point for the Mona Lisa effect (38° of slant rotation) for real pictures was considerably lower than the break-down point for simulated slant (70°) in Exp.1. Another marked difference is that we did not find any effect of picture type, thus the effect broke down for face photograph, cartoon, and smiley in a similar way. This result clearly speaks against compensation theory as a number of cues were available to surface slant here that were missing in the computer images used in Exp. 1. Seeing the physical rotation may have focused attention on the slant of the picture surface and thereby created a re-evaluation of the gaze direction, more so than in the case of the simulation.

Experiment 3: Boxes

The Mona Lisa effect is a special case of the differential rotation effect (Goldstein, 1979). According to the differential rotation effect, if any depicted or photographed object has an orientation in virtual space that is perpendicular to the picture surface, this object will point at the observer at any vantage point. In other words, the rotation effect is not germane to portraits but it can be found in all extended objects. Can we ask whether an orientation-specific object "looks" at us. It may be problematic at many levels, but as an aside, we were interested to find out if observers would interpret object pointing in a similar fashion as gaze direction. Thus, in the third Experiment we tested whether the limits of robustness that we found for the faces generalize to simple objects, be they photographed objects or drawings. To do so we used the same simulated slant design as in Experiment 1. Are simple objects equally robust in the face of extreme slant?

Methods

Participants. 12 volunteers (10 female and 2 male) were newly recruited and participated in this experiment. Their average age was 23 (*SD* = 2.7) years. All participants had normal or corrected to normal vision and were naïve about the purpose of the experiment.

Stimuli. We used two kinds of pictures: a photograph of a metallic box and a simple sketch of a similar box. In Figure 7 they are both oriented with their longer side in the frontoparallel plane. The pictures were presented as in Experiment 1 either on white background (Top Panel) or on grey background (Bottom Panel) such that they appeared to be framed.

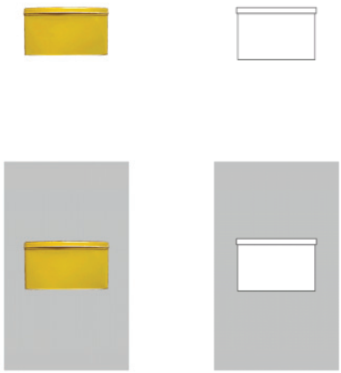

Figure 7. Pictures (frontal view) used in Experiment 2: box photograph and box sketch. *Top panel:* pictures on white background; *bottom panel:* pictures on grey background, here referred to as frame. (Online in color.)

Design, equipment and procedure. The design, equipment and procedure were identical to those in Experiment 1. Instead of answering questions about the eye-contact, here observers decided if the box was pointing directly at them.

Results and Discussion

We found the rotation effect also for the pictures of these simple objects, however, the effect was not as strong as for pictures of faces. The photographed and the drawn box both continued to point at the observer up to about 45° of simulated slant with respect to the frontoparallel plane. Figure 8 shows the pictures rotated in yaw by 45 degrees counter-clockwise around the vertical axis.

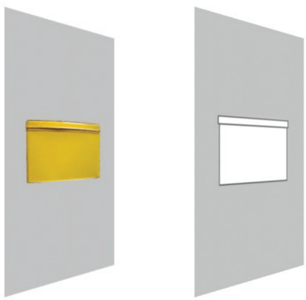

Figure 8. The photographed and the drawn box both rotated by 45 degrees counter-clockwise around the vertical axis. (Online in color.)

On average, the rotation effect broke down at a slant of 44.81° (*SD* = 11.73) for the photographed box and at a slant of 45.12° (*SD* = 13.13) for the drawn box. The picture type (photographed vs. drawn) had no influence on the break-down point of the rotation effect: $F(1, 11) = .07$, $p = .792$, $\eta^2 = .01$. We also did not find any significant effect of frame $F(1, 11) = .01$, $p = .916$, $\eta^2 < .01$. There was a trend of initial orientation on the limits of the rotation effect, however, it was statistically not significant: $F(1, 11) = .26$, $p = .621$, $\eta^2 = .02$. Thus, we observed no anchoring-effect. If anything, the trend points in the opposite direction, the box appeared to point at the observer longer if the observer started with the side view.

The direction of picture slant had no significant influence on the rotation effect: $F(3, 33) = 1.38$, $p = .266$, $\eta^2 = .11$. The rotation effect appeared to break down at about the same angle (consult Figure 9).

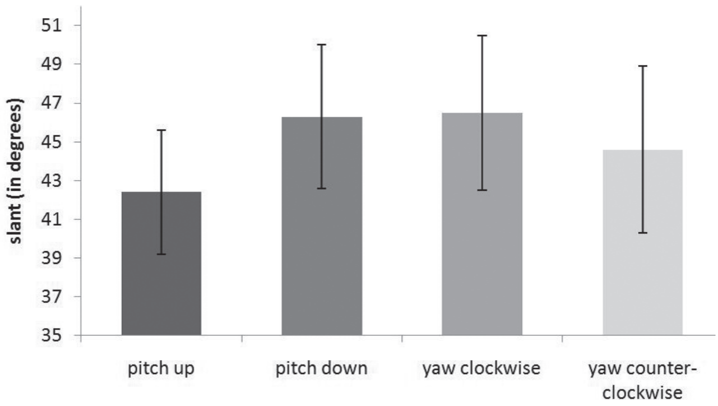

Figure 9. The averaged break-down points for the rotation effect for all four slant directions in Experiment 2. Error bars indicate standard errors of the mean.

The faces used in Experiment 1 produced larger tolerable rotations than the boxes used here. We conducted a t-Test on the slant values of the photographed face (Exp. 1) vs. the photographed box $t(29) = 6.3$, $p < .001$. It appears that the mechanism that allows us to discount the perspective distortions is optimized for faces, which carries over to face-like stimuli. Arguably the task to determine the pointing of an object may also be altogether different from the task to judge mutual gaze.

General Discussion

We have investigated the limits of Mona Lisa effect vis-à-vis physical and simulated slant of the picture surface. The eyes of a portrait appear to follow the observer and maintain eye-contact across changing vantage points. The effect is remarkably robust in the face of perspective picture transformations. For simulated pictures, the Mona Lisa effect did not break down until slants of up to 70°, for physical pictures, however, slant was only tolerated up to 38° of rotation out of the frontoparallel plane. Additionally we tested whether the Mona Lisa effect is limited to elaborate portraits. This is not the case, the effect extends to cartoon faces and smileys, albeit with a small loss in robustness for simulated picture slant. A similar rotation effect exists with respect to the egocentric orientation of objects.

Our observers consistently reported that they maintained eye contact with the face on the picture regardless of the slant direction: photos of faces can be virtually slanted by up to 70º before a subjective deflection of the gaze direction is noticed. That is, the Mona Lisa effect breaks down when perspective picture transformation exceeds this limit. The removal of information about the picture's orientation in physical space seemed to play a role in this remarkable tolerance. The photographs of the real human face were more robust than the less detailed cartoon faces, and the latter were more robust than the even less detailed smiley faces. The Mona Lisa effect broke down for smileys at about 58º of simulated slant. Perhaps, the configurational information carried by features other than the eyes are responsible for the superior robustness of the photographed face (see Fig. 10). When simple rectangular objects were used instead of the faces, the robustness toward slant was further reduced. All boxes started to be affected by slants exceeding 45º, but note that the task to judge orientation may be vastly different from judging gaze direction.

Virtual picture slant in the downward direction produced more robustness for all types of pictures. This may be explained by configural features within the image: the eyes maintain their projected separation during downward slant but not so during sideways slant. However, the same pattern (downward pitch was tolerated better than upward pitch) was found also for pictures of boxes, practically devoid of configurational information. It is thus more likely that our familiarity with sideways slant (vertical rotation axis) is the source to understanding the effect of slant direction.

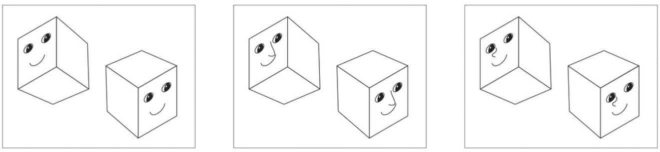

Figure 10. Configurational aspects can alter the Mona Lisa effect. Note that the apparent eye direction changes with the orientation of the cube, but less so when a nose is added. (Drawings by A. K.)

In the experiment with simulated slant, the frame did not matter much, which calls into doubt or at least relativizes the compensation idea. Compensation theory predicts the compensation of pictorial space distortions only when the picture surface slant is (more or less) visible (e.g., Yang & Kubovy, 1999). The frame varied picture surface visibility, it was either emphasized by the frame or only implicitly available. The observers compensated perspective transformations of framed and unframed pictures to equal degrees, if they compensated at all. Although the Mona Lisa effect broke down marginally later for pictures with a frame, the visibility of the picture surface was not essential. The frame mattered much less than the type of object and the level of detail. Our results do thus not support the notion of compensation. Neither do they support the notion that the effect is easily explained by an estimate of local surface orientation (Vishwanath, Girshick, & Banks, 2005).

Surprisingly, when participants were confronted with a physical surface that they could slant themselves, the Mona Lisa effect broke down much earlier (at 38° of slant), regardless of picture type. This outcome is difficult to interpret. The proprioceptive information about the rotation angle and/or the motor efferences initiating the picture slant clearly put stronger emphasis on the picture slant. This may have made it more akin to a real 3D face and thus reduced the Mona Lisa effect.

In all our stimuli the object and its configuration (face and eyes or box) remained perceptually intact beyond the breakdown point. So why did the Mona Lisa effect break down between 40° and 70°? A number of explanations (other than compensation) for the limit of the rotation effect could be entertained, but it appears that the notion of array-specificity (Halloran, 1989) or its qualification by Todorović (2009) are best suited for the job. Our unexpected result that physically slanting the picture causes a much earlier break-down of the Mona Lisa effect than does computer-simulated slant is best accommodated by Todorović's (2009) account of eccentricity. The information contained in the projected relation of the inner facial features within the head outline as a decisive cue to head and gaze orientation is germane to faces. And pictures of faces appear to suffer most in terms of robustness when they are slanted by means of a physical device. Thus, we may witness a rivalry between the pictorial Mona Lisa effect on the one hand and the realization of physical picture slant on the other hand. In this situation, the advantages provided by facial eccentricity features are reduced.

In sum, the Mona Lisa effect is astonishingly robust toward picture slant when the latter is simulated (up to 70°) but less so when the picture is physically slanted (up to 38°). The richness of visual cues and similarity to a real human face increased the robustness of the Mona Lisa effect substantially, however, only in the case of virtual surface slant. Anchoring effects were not present and thus did not influence the robustness of the Mona Lisa effect.

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