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Head rotation and the perception of eyelid height and contour

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ABSTRACT

Purpose Effective visual perceptual processing is one of the many components of surgical competence. Human face identification is most efficient when viewed upright. However, it is not yet clear how this perception sensitivity impacts eyelid symmetry. This study investigates surgeons' and laypeople's accuracy and efficiency in perceiving eyelid asymmetry from different spatial perspectives.

Methods A prospective psychometric experiment was conducted where oculoplastic surgeons were recruited from the American Society of Ophthalmic Plastic and Reconstructive Surgery and the Brazilian Oculoplastic Surgery Society, and control participants were recruited via crowdsourcing (Amazon's Mechanical Turk). Standard illustrations of the human face with varying degrees of eyelid abnormality, laterality, gender and rotation were presented to participants who were asked to judge whether the eyelids were symmetric or asymmetric.

Results The survey was completed by 75 oculoplastic surgeons (49.33% male; mean age of 46.9±10.7) and 192 lay individuals (54.6% male; mean age 34.6±11.3 years). Among oculoplastic surgeons, deviation from upright was significantly associated with increased reaction time and decreased proportion correct (OR per 45° for peak 0.68, 95% CI 0.60 to 0.77, p<0.001; OR per 45° for ptosis 0.52, 95% CI 0.32 to 0.87, p=0.012; OR per 180° for aggregate responses 0.56, 95% CI 0.51 to 0.61, p<0.001). Oculoplastic surgeons demonstrated increasing accuracy and decreasing reaction time with additional trials for both peak and ptosis.

Conclusion Oculoplastic surgeons perceive eyelid asymmetries more accurately and can better compensate for inverted sensory information. However, accuracy increases and reaction time decreases with additional trials, suggesting trainability and potential for improvement in inversion disability.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Effective visual perceptual processing is one of the many components of surgical competence. Human face identification is most efficient when viewed upright. However, it is not yet clear how this perception sensitivity impacts eyelid symmetry.

WHAT THIS STUDY ADDS

⇒ Degree of rotation away from upright was associated with lower odds of a correct response on assessment of ptosis and peak abnormalities. Surgeons, although more accurate than laypeople, are affected by significant perception challenges when faces are inverted, demonstrating decreased accuracy and increased reaction time when assessing lateral peak, medial peak, mild and severe ptosis at all degrees of rotation away from upright.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Although trained in assessing eyelid asymmetries, oculoplastic surgeons demonstrate less accuracy and longer reaction time with all spatial deviations from upright. Compensation may require more intricate mental processing, evidenced by increased reaction time when compared with lay observers, with implications for perceptual processing of facial and periocular structures.

INTRODUCTION

Effective visual perceptual processing is one of the many components of surgical competence.[1] Though mostly innate in ability, the facial surgeon is constantly reviewing facial structures from different angles to recognise critical features. One particular instance of such dynamic recognition is in the performance of surgery from a head-of-bed position, where the surgeon is reviewing the patient in an upside-down state. In this state, the surgeon must make decisions regarding subtle changes in symmetry and contour with an inverted image.

While the human perceptual system is tuned to recognise faces from an extremely early age with a high level of accuracy,[2] orientation of the image is important in performing this task accurately.[3 4] For untrained humans matching generic rotated objects, accuracy tends to decrease and task time increases with degree of rotation.[5–7] It is not clear if the same processes are at play in facial recognition.

One important application of accurate perception of rotating faces and objects is in oculoplastic surgery. During eyelid surgery (eg, ptosis, blepharoplasty, reconstruction, canthoplasty), these skills are taxed as surgeons are often positioned superiorly or laterally to the patient's head, altering the angle of observation. Many physicians sit a patient upright during ptosis surgery to assess the eyelid height, contour and symmetry.[4 8 9] Though many factors are involved in this intraoperative manoeuvre, physician perception in an upright position may be a significant component.

This investigation aims to evaluate perceptual aspects of this process by presenting rotated faces of varying asymmetry to laypeople and surgeons in order to better understand their accuracy and processing time in making these decisions under various rotational conditions, with a focus on highlighting perceptual processing and challenges among oculoplastic surgeons.[10]

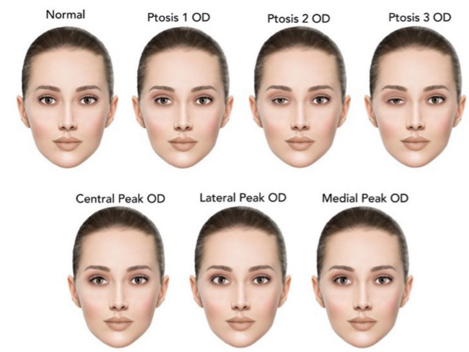

Figure 1 Variation in the right eye height and contour in the female model.

METHODS

Study design and setting

This prospective observational study recruited both layperson participants (individuals without expert knowledge in medicine, surgery, oculoplastic surgery or facial plastic surgery) and oculoplastic surgeons. Layperson participants were recruited from Amazon's Mechanical Turk (MTurk). MTurk is a crowdsourcing marketplace enabling individuals, businesses or researchers to outsource tasks to a globally distributed workforce and has been found to yield results comparable to more conventional sampling methods.[11] MTurk participants were compensated approximately US$1 per fully completed survey. Oculoplastic surgeons were recruited via a direct-to-participant email solicitation of participation. The experiment in both groups was performed electronically from the participants' personal computer.

No identifiable clinic or radiographic photographs were used in this study. Patients and the public were not involved in the design, conduct, reporting or dissemination plans of our research, however, patients and the public were participants in the research itself, as mentioned above.

Participants were presented with a series of realistic digitally drawn faces depicting eyelid asymmetry varying in type and severity. These images were displayed at different rotation axes, and participants were instructed to classify the eyes in the image as symmetric or asymmetric, as quickly as possible, by pressing a key on their keyboard.

Image development

Images were designed by an illustrator and depicted three levels of ptosis (mild, moderate and severe) and three different eyelid contour variations (lateral, central and medial peaks) for both the right and left eyes in male and female models (figure 1). These images were rotated to eight different axis positions using Adobe Photoshop V.21.0.1 (online supplemental figure 1). This resulted in a series of images encompassing all possible combinations of ptosis (three levels) or contour (three levels), sex (two levels), rotation (eight levels) and laterality (two levels). Normal images were included for each sex and rotation position combination (16 total). These normal images were interspersed at a 3:1 abnormal to normal ratio.

During a pilot study, the images with moderate ptosis (ptosis two in figure 1) and a central peak (central peak in figure 1) were found to be correctly classified approximately 50% of the time. As these images provided no additional value to the experiment, they were omitted for the main experiment participants. Therefore 'ptosis A' represented mild ptosis, 'ptosis B' represented severe ptosis, 'peak A' represented lateral peak and 'peak B' represented medial peak. Thus, the final set of experimental images was composed of 128 asymmetric images and 48 symmetric controls defined.

Experiment design

A protocol was built using the PsychoPy3 software, an open source Python-based software program commonly used in neuroscience and experimental psychology.[10] The first component collected demographic information from participants and explained the purpose of the experiment. Participants were instructed to sit approximately 50 cm from the display and judge whether the eyelids of the face presented were symmetric or asymmetric by pressing one of two designated computer keys ('s' and 'a', respectively) as fast as possible. Participants first completed a short tutorial using five randomly selected images and were given feedback regarding their results in terms of accuracy and reaction time (RT).

After completion of the tutorial, the 192 images were presented in random order and the participants classified them as symmetric or asymmetric without feedback on their performance. Each image and response pair was defined as a single trial. Participants were given a 250 ms break between trials. The survey was hosted on Pavlovia (www.pavlovia.org), an online repository for PsychoPy experiments, and all survey responses saved on the server.

Statistical considerations

The primary outcome measures were the proportion of trials with correct perception of eyelid symmetry and the RT for correct responses. The exposure of interest was a degree of rotation. All participants with repeated trials (ie, participants who mistakenly took the survey more than once) and all trials with RTs below 200 ms (ie, below the limit of human RT to visual stimuli) were excluded from the analyses.

Mixed effects logistic regression models with participant random intercepts were used to assess associations between the proportion of trials with correct perception of the eyelid symmetry. Coefficients from these models are shown as OR. Associations with the RT for correct responses were assessed using a generalised mixed effects linear regression model with logarithmic linkage and participant random intercepts, to account for clustering at the participant level. Coefficients from this generalised model are reported as multiplicative effects (ie, percentage change) through the exponentiation of the coefficients (e^b). All analyses conducted in Stata V.17.0, StataCorp.

RESULTS

Aggregate data (all participants)

The experiment was completed a total of 271 times, of these 4 (~1.5%) were individuals who completed duplicate sessions and their duplicate sessions were excluded from further analyses. Of the remaining 267 unique individuals, 196 were laypersons assessing 192 images each and 75 were surgeons (N=43 practising in the USA; N=32 practising in Brazil) assessing 96 images each (ie, each completing a random half of the trials). In total, there were 44832 trials.

Mean age of the layperson participants was 34.6 years old (SD 11.3) and 107 (55%) were male. Mean age of the surgeons was 46.9 years old ((SD) 10.7) and 37 (49%) were male. Of the 44832 trials, 2987 (6.7%) had RTs below the 200 ms limit, which were exclusively from laypersons, and were excluded from further analysis. Of the remaining 41845 trials, median RT for correct responses was 1.27 s (IQR 0.89–1.98 s) and 28717 (68.6%) were answered correctly (ie, correctly classified as symmetric or asymmetric).

Overall, surgeons were more likely to have slower RTs (2.77 vs 1.40 s, p<0.001) and more likely to provide a correct response when compared with laypeople (88% vs 64% correct, p<0.001) (online supplemental table 1). Similarly, the aggregate proportion of correct responses was greater for surgeons than for laypersons for the peak A (OR=14.2, p<0.001), peak B (OR=7.1, p<0.001), ptosis A (OR=16.7, p<0.001) and ptosis B (OR=25.6, p<0.001) conditions (online supplemental table 1). Both RT and accuracy were significantly improved in upright when compared with the 180 inverted position for both experimental groups together (e^b=0.91, p<0.001; OR=1.78, p<0.001). Furthermore, degree of rotation away from upright was associated with a lower odds of correct response when all images were aggregated together (OR_{180} 0.56, 95% CI 0.51 to 0.61, p<0.001) and these exhibited a linear trend of decreasing odds with increasing rotation away from 0° (OR=0.86 per 45°, p<0.001). RT increased as a function of the degree of rotation away from upright when all images were aggregated together (e^b=1.02 per 45°, p<0.001).

There was no significant association between the abnormal eye (left or right) and the proportion correct responses (OR=0.98, p=0.360) or RT (e^b=1.00, p=0.920) when analysing aggregated images, or images stratified by type of asymmetry and severity. There was additionally no association noted between concordance of the direction of rotation (ie, leftward vs rightward) and the eye demonstrating abnormality (ie, left or right) on the proportion correct (p=0.360) or RT for correct answers (p=0.120). Further, there was no difference in accuracy or RT between paired leftward and rightward rotations for the following pairs: 45 vs 315, 90 vs 270 and 135 vs 225. Thus, the left and right eye trials were collapsed for each rotation position, and similarly the paired rotations leftward and rightward were additionally collapsed for further analysis.

There was an association between the sex of the face displayed in the image and both the aggregate proportion correct and RT. Specifically, a male face was associated with a lower odds of correct classification (OR 0.85, 95% CI 0.81 to 0.89, p<0.001) and a faster RT (e^b=0.98, 95% CI 0.95 to 0.99, p=0.013) corresponding to a percentage correct difference of 2.4% and RT difference of 42.9 ms. There was no significant association between the sex of the observer and the sex of the image presented in terms of accuracy or RT.

Within group oculoplastic surgeon results segmented by eyelid asymmetry

Among the surgeon group, the overall proportion of correctly classified images was highest for normal and ptosis and lowest for peak B (online supplemental figure 2). The overall RT was the shortest for ptosis B, followed by ptosis A and peak A. Normal images had the longest RTs. Similarly, among the layperson group, the overall proportion of correctly classified images was highest for normal and ptosis B and lowest for peak B (online supplemental figure 2). The shortest average RT was for ptosis B, followed by normal and ptosis A for laypeople, with peak A and peak B demonstrating the longest RTs.

Peak

For peak, degree of rotation away from upright was associated with lower odds of a correct response ($OR_{\text{Peak A}}$ =0.71 and $OR_{\text{Peak B}}$ = 0.68 per 45°, p<0.001) (table 1). Peak B demonstrated a lower proportion of correct responses than peak A (OR=0.50, p<0.001) (table 3), with the greatest difference in proportion of correct responses noted at more extreme degrees of rotation (180° OR=0.32, p<0.001). All peaks exhibited a linear trend with decreasing odds of correct identification as images rotated further from upright (ORs=0.71 and 0.68 p<0.001, for peaks A and B, respectively) (table 1). The odds of correctly identifying asymmetry were significantly better in the upright than inverted position for

Table 1 Proportion correct as a function of degree of rotation

Rotation	Laypersons—peak condition				Laypersons—ptosis condition			
	Peak A		Peak B		Ptosis A		Ptosis B	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Per 45°	0.71 (0.68 to 0.75)	<0.001	0.76 (0.73 to 0.80)	<0.001	0.66 (0.63 to 0.70)	<0.001	0.84 (0.78 to 0.91)	<0.001
Category								
0°	3.85 (2.95 to 5.02)	<0.001	3.02 (2.35 to 3.87)	<0.001	5.29 (4.08 to 6.85)	<0.001	1.69 (1.13 to 2.51)	0.01
45°	2.18 (1.74 to 2.74)	<0.001	1.78 (1.43 to 2.21)	<0.001	3.20 (2.58 to 3.98)	<0.001	1.36 (0.97 to 1.89)	0.071
90°	1.29 (1.03 to 1.62)	0.027	1.17 (0.94 to 1.46)	0.155	1.71 (1.38 to 2.11)	<0.001	0.95 (0.69 to 1.32)	0.777
135°	1.12 (0.89 to 1.40)	0.348	1.09 (0.88 to 1.36)	0.420	1.41 (1.14 to 1.75)	0.001	0.80 (0.58 to 1.11)	0.180
180°	Ref		Ref		Ref		Ref	
	Surgeons – Peak Condition				Surgeons – Ptosis Condition			
	Peak A		Peak B		Ptosis A		Ptosis B	
Rotation	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Per 45°	0.71 (0.61 to 0.82)	<0.001	0.68 (0.60 to 0.77)	<0.001	0.61 (0.51 to 0.75)	<0.001	0.52 (0.32 to 0.87)	0.012
Category								
0°	2.38 (1.07 to 5.27)	0.032	7.01 (3.48 to 14.1)	<0.001	6.73 (2.27 to 19.9)	<0.001	8.80 (0.43 to 182)	0.159
45°	2.66 (1.35 to 5.23)	0.004	2.16 (1.30 to 3.61)	0.003	6.61 (2.81 to 15.6)	<0.001	8.25 (1.10 to 61.9)	0.040
90°	0.60 (0.33 to 1.10)	0.098	1.52 (0.92 to 2.50)	0.101	1.38 (0.73 to 2.62)	0.322	2.45 (0.46 to 13.0)	0.290
135°	0.60 (0.33 to 1.10)	0.100	1.30 (0.78 to 2.19)	0.312	1.55 (0.77 to 3.12)	0.215	1.15 (0.27 to 4.85)	0.852
180°	Ref		Ref		Ref		Ref	

Statistical testing conducted using mixed effects logistic regression model.

peak A and peak B (OR=2.38, p=0.032 and OR=7.01, p<0.001, respectively) (table 1).

Peak A was associated with a longer RT for images at 90° and 135° of rotation relative to upright images (e^b=1.22–1.33 to p<0.050) but not for images at 180° of rotation (table 2). A linear trend of increasing RT per 45° rotation was significant for Peak A (e^b=1.04, p=0.018) (table 2). Peak B, however, only demonstrated evidence of a significantly increased RT for images rotated 180° relative to upright (e^b=1.63, p<0.001). Similar to peak A, evidence of a linear increase in RT across rotations of Peak B was noted (e^b=1.12 per 45°, p<0.001) (table 2).

Ptosis

For ptosis, greater degree of rotation away from upright was associated with decreasing accuracy after 45° ($OR_{ptosis\ A}$= 0.61, p<0.001 and $OR_{ptosis\ B}$= 0.52, p=0.012 per 45°) (table 1). While the most severe version of ptosis (ie, ptosis B) showed higher odds of correct identification overall compared with ptosis A (OR=6.1, p<0.001) (table 3), this difference was driven by higher odds of a correct response for ptosis greater than 45° of rotation. Indeed, there were no reliable differences in correctly identifying ptosis A versus B at upright or 45° of rotation ($OR_{upright}$=5.65, p=0.190; OR_{45}=2.96, p=0.090). For ptosis A, the odds of correctly identifying asymmetry were significantly better in the upright than inverted position (OR=6.73, p<0.001), however, for ptosis B this relationship was not significant (OR=8.80, p=0.159) (table 1).

With respect to RT, images with the most severe degree of ptosis (ie, ptosis B) were identified faster than less severe ptosis (ie, ptosis A) at all degrees of rotation (e^b=0.49, p<0.001) (table 4). Ptosis A was associated with significantly longer RTs as the degrees of rotation increased (e^b=1.11 per 45° increase, p<0.001). A similar trend was noted for ptosis B; however, the change in RT per 45° of rotation was less pronounced for Ptosis B (e^b=1.02 per 45° increase, p<0.001) (table 2).

DISCUSSION

This study sought to examine the accuracy and efficiency of perception of facial features, more specifically eyelid asymmetry when viewed from different rotational perspectives. The first finding suggests that for both laypeople and surgeons, correctly identifying asymmetry appeared to depend on the type and severity of asymmetry. For both groups, the odds of correctly identifying asymmetry were highest for more severe asymmetry, and higher for ptosis when compared with peak. The second result relates to the rotation of the facial depiction. There was a significant inverse linear relationship between the proportion of correct responses and the degree of rotation away from upright. The greater the degree of rotation away from upright, the less accurate observations were for both peak and ptosis, in all groups, with the greatest error found in the inverted position, even for oculoplastic surgeons trained at perceiving eyelid asymmetry. Even expert oculoplastic surgeons with extensive practice experience suffer from significant inversion disability, in that they are less accurate at defining small differences in contour and eyelid position when viewed in an inverted position relative to upright.

Expectedly, surgeons were overall more accurate (and spent more time on each trial) than laypersons. However, oculoplastic surgeons are subject to similar perceptual challenges with the rotational task, leading to diminished perceptual accuracy as rotation is increased, with particular significant challenges performing symmetry assessments in the inverted position. Stated alternatively, surgeons were more accurate overall but the trend line to worsening accuracy in the inverted position was the same (the regression functions are roughly parallel). The impact of such observations on visual processing of facial asymmetries may be exemplified by further discussing eyelid surgeries such as ptosis surgery, which require iterative recognition of minute asymmetries at different orientations in space. The most common complications of ptosis surgery are uneven or asymmetric eyelid height, poor contour or eyelid peaking.[12] Intraoperatively, correction of eyelid ptosis is frequently evaluated with the patient in an upright primary position.[9 12] This process is time-consuming as well as logistically and ergonomically challenging, both for patients and surgeons. Beyond the time and logistics, there are also safety concerns in sitting patients up with significant variations in haemodynamic measures and oxygenation in sitting versus supine position.[13] However, surgeons often perform this task, and the findings from this study suggest that upright positioning is crucial to achieving the highest perceptual accuracy. It is not clear what aspects of positioning the patient upright are critical. It is unlikely that gravity plays a role,[14] and the eye projection is also likely stable.[15] Purported stimulation of the wakeful state in the patient (or at least enhancing arousal) may contribute to the upright assessment, though this is unproven. The role of the surgeon's perceptual challenges has been underappreciated in this process. This study suggests that, whether consciously or not, the surgeon can increase perceptual ease and improve accuracy of asymmetry assessment by viewing the patient upright. Whether this is by assessing the patient in the upright position or some other perceptual trick such as using a mirror or changing surgeon position to view from below.

This study further demonstrates that this process is roughly linear, in that accuracy decreases in a stepwise manner as the image is rotated away from upright. Oculoplastic surgeons may be seven times less likely to accurately perceiving a lateral peak and nine times less likely to perceive small amounts of ptosis in the inverted position. However, even for smaller degrees of rotation away from upright such as 45° (as might be created by head tilt in the office), surgeons are almost three times less likely to correctly perceive lateral peak. While a 45° rotation at bedside (achieved via surgeon positioning) may result in increased accuracy compared with the inverted position, it may not be practically useful in the operating

Table 2 Reaction time as a function of degree of rotation

	Laypersons—peak condition				Laypersons—ptosis condition			
	Peak A		Peak B		Ptosis A		Ptosis B	
Rotation	e^b (95% CI)	P value	OR (95% CI)	P value	e^b (95% CI)	P value	e^b (95% CI)	P value
Per 45°	1.14 (1.11 to 1.17)	<0.001	1.05 (1.01 to 1.09)	0.005	1.21 (1.16 to 1.25)	<0.001	1.03 (1.02 to 1.05)	<0.001
Category								
0°	Ref		Ref		Ref		Ref	
45°	0.99 (0.86 to 1.14)	0.905	1.02 (0.88 to 1.19)	0.777	1.05 (0.89 to 1.22)	0.569	1.07 (0.98 to 1.17)	0.147
90°	1.20 (1.05 to 1.37)	0.008	1.11 (0.95 to 1.29)	0.192	1.50 (1.28 to 1.74)	<0.001	1.22 (1.12 to 1.33)	<0.001
135°	1.93 (1.71 to 2.19)	<0.001	1.35 (1.17 to 1.56)	<0.001	2.30 (1.97 to 2.69)	<0.001	1.12 (1.02 to 1.22)	0.017
180°	1.18 (1.00 to 1.39)	0.048	1.02 (0.84 to 1.22)	0.871	1.74 (1.44 to 2.09)	<0.001	1.19 (1.07 to 1.31)	<0.001
	Surgeons—peak condition				**Surgeons—ptosis condition**			
	Peak A		**Peak B**		**Ptosis A**		**Ptosis B**	
Rotation	**e^b (95% CI)**	**P value**	**OR (95% CI)**	**P value**	**e^b (95% CI)**	**P value**	**e^b (95% CI)**	**P value**
Per 45°	1.04 (1.01 to 1.08)	0.018	1.12 (1.07 to 1.18)	<0.001	1.11 (1.09 to 1.14)	<0.001	1.02 (1.01 to 1.04)	0.006
Category								
0°	Ref		Ref		Ref		Ref	
45°	1.17 (0.98 to 1.38)	0.081	0.97 (0.79 to 1.19)	0.785	1.21 (1.07 to 1.37)	0.002	0.98 (0.92 to 1.05)	0.644
90°	1.22 (1.03 to 1.46)	0.022	0.99 (0.81 to 1.22)	0.953	1.55 (1.38 to 1.75)	<0.001	1.06 (1.00 to 1.13)	0.059
135°	1.33 (1.12 to 1.57)	0.001	1.01 (0.83 to 1.23)	0.947	1.83 (1.62 to 2.07)	<0.001	1.08 (1.01 to 1.15)	0.021
180°	1.16 (0.96 to 1.42)	0.131	1.63 (1.34 to 1.99)	<0.001	1.43 (1.25 to 1.63)	<0.001	1.03 (0.96 to 1.11)	0.445

Statistical testing conducted using generalised mixed effects linear regression model with logarithmic linkage.
e^b=exponentiated coefficient. Interpreted as $(e^b-1)-100$=percentage difference in reaction time.

Table 3 Proportion correct within degree of rotation between condition severity

	Laypersons—peak condition				Laypersons—ptosis condition			
Rotation	Peak A	Peak B	OR (95% CI)	P value	Ptosis A	Ptosis B	OR (95% CI)	P value
0°–180°	43.8%	37.8%	0.70 (0.64 to 0.77)	<0.001	52.7%	85.3%	8.94 (8.01 to 9.98)	<0.001
0°	58.1%	51.1%	0.66 (0.51 to 0.85)	0.001	68.6%	88.7%	5.94 (4.16 to 8.49)	<0.001
45°	48.9%	41.5%	0.64 (0.54 to 0.77)	<0.001	60.6%	87.1%	8.40 (6.59 to 10.72)	<0.001
90°	41.1%	34.9%	0.68 (0.57 to 0.82)	<0.001	49.9%	85.0%	11.02 (8.73 to 13.90)	<0.001
135°	39.2%	34.0%	0.72 (0.60 to 0.87)	<0.001	46.6%	83.6%	10.01 (8.06 to 12.43)	<0.001
180°	36.6%	32.1%	0.73 (0.55 to 0.96)	0.022	40.5%	85.4%	15.09 (10.87 to 20.93)	<0.001
	Surgeons—peak condition				**Surgeons—ptosis condition**			
Rotation	**Peak A**	**Peak B**	**OR (95% CI)**	**P value**	**Ptosis A**	**Ptosis B**	**OR (95% CI)**	**P value**
0°–180°	82.1%	72.8%	0.50 (0.40 to 0.63)	<0.001	91.1%	98.1%	6.07 (3.63 to 10.16)	<0.001
0°	89.5%	87.2%	0.71 (0.26 to 1.93)	0.499	97.1%	99.2%	5.65 (0.42 to 76.28)	0.192
45°	90.0%	76.0%	0.26 (0.15 to 0.45)	<0.001	96.6%	98.6%	2.96 (0.84 to 10.44)	0.091
90°	76.5%	73.0%	0.79 (0.51 to 1.22)	0.282	88.0%	98.1%	10.39 (3.60 to 30.00)	<0.001
135°	76.2%	64.8%	0.48 (0.29 to 0.78)	0.003	87.4%	97.0%	6.91 (2.57 to 18.55)	<0.001
180°	82.7%	66.5%	0.32 (0.16 to 0.62)	<0.001	86.0%	96.4%	6.84 (2.10 to 22.28)	0.001

Statistical testing conducted using mixed effects logistic regression model within rotation strata.

room. Rather, the 45° rotation away from upright demonstrates a step in the linear process of perception disability from upright to inverted positioning. These findings are not surprising in the context of the broader visual perception literature, where now classic experiments in the 1970 were able to show similar findings in that accuracy in identifying pairs of rotated three-dimensional (3D) structures decreased linearly with degree of rotation.[7] Overall, these findings suggest that although oculoplastic surgeons are experts at perceiving eyelid asymmetry, they are subject to similar perceptual challenges as the lay population. Recognising these limitations may improve aesthetic and functional surgical outcomes.

Interestingly, both laypersons and surgeons were best able to correctly appreciate severe ptosis, and among surgeons there was no significant difference in perception of severe ptosis in the upright versus inverted position. Thus, the degree of asymmetry affects accuracy of

Table 4 Reaction time within degree of rotation between condition severity

	Laypersons—peak Condition				Laypersons—ptosis condition			
Rotation	Peak A	Peak B	e^b (95% CI)	P value	Ptosis A	Ptosis B	e^b (95% CI)	P value
0°–180°	1.64	1.84	1.12 (1.05 to 1.19)	<0.001	1.69	0.97	0.58 (0.55 to 0.61)	<0.001
0°	1.27	1.85	1.46 (1.24 to 1.72)	<0.001	1.42	0.84	0.59 (0.54 to 0.65)	<0.001
45°	1.57	1.83	1.17 (1.10 to 1.24)	<0.001	1.56	0.96	0.62 (0.58 to 0.65)	<0.001
90°	1.64	1.80	1.10 (1.02 to 1.18)	0.016	1.76	1.07	0.61 (0.55 to 0.67)	<0.001
135°	2.04	1.60	0.79 (0.65 to 0.96)	0.017	2.15	0.39	0.18 (0.15 to 0.22)	<0.001
180°	1.44	1.85	1.29 (1.13 to 1.46)	<0.001	1.78	0.96	0.54 (0.48 to 0.60)	<0.001
	Surgeons—peak condition				**Surgeons—ptosis condition**			
Rotation	**Peak A**	**Peak B**	**e^b (95% CI)**	**P value**	**Ptosis A**	**Ptosis B**	**e^b (95% CI)**	**P value**
0°–180°	2.45	3.53	1.44 (1.34 to 1.55)	<0.001	2.37	1.17	0.49 (0.47 to 0.52)	<0.001
0°	2.02	3.09	1.53 (1.29 to 1.81)	<0.001	1.68	1.13	0.68 (0.61 to 0.74)	<0.001
45°	2.50	3.30	1.32 (1.15 to 1.53)	<0.001	2.02	1.16	0.58 (0.53 to 0.62)	<0.001
90°	2.56	3.44	1.35 (1.18 to 1.53)	<0.001	2.65	1.14	0.43 (0.40 to 0.47)	<0.001
135°	2.96	3.28	1.11 (0.97 to 1.26)	0.117	3.18	0.95	0.30 (0.27 to 0.34)	<0.001
180°	1.71	4.25	2.48 (1.74 to 3.54)	<0.001	2.32	1.06	0.46 (0.41 to 0.51)	<0.001

Statistical testing conducted using generalised mixed effects linear regression model with logarithmic linkage within rotation strata.
e^b=exponentiated coefficient. Interpreted as $(e^b-1)\times 100$=percentage difference in reaction time.

perception, with larger asymmetries being easier to recognise. This is not surprising given previous studies showing that ptosis asymmetry in laypeople can be recognised more than 90% of average observers can identify 2 mm of ptosis asymmetry accurately.[16] This finding unfortunately has minimal application to the perceptual tasks involved in eyelid surgery. Although patients may present initially with severe ptosis, intraoperative adjustments in ptosis surgery involve appreciating more minute differences in peak and ptosis. These smaller adjustments would more closely correspond to the mild ptosis and medial or lateral peak in this study, which were significantly more accurately perceived in upright position. Thus, even in cases of severe baseline ptosis, the perceptual challenges presented with inverted viewing are involved in the critical intraoperative tasks.

This study also demonstrated difference in sensitivity to asymmetry type, peak or ptosis. Although marginal peak is a major determinant of upper eyelid contour and horizontal position, both medial and lateral peak position were perceived less accurately by both surgeons and laypeople in this study. This is in line with past studies that have discussed the challenge in achieving and quantifying symmetric contour.[17 18] Digital image analysis techniques to quantify peak have only further emphasised the importance of considering perception of peak asymmetry by showing that a nasal shift of peak can be extreme in cases of involutional ptosis, and correction of ptosis is associated with a temporal shift in peak.[17] Such cases may be prime candidates for upright viewing.

These results may have implications beyond ptosis surgery, for other facial plastic surgeries. The production and execution of symmetric incision lines in surgery such as blepharoplasty, pretrichial brow surgery and cheiloplasty is critical in the determination of functional and aesthetic outcomes.[19] Studies have shown an effect of handedness on surgical outcomes,[20–22] which may interact with perceptual rotational challenges. Other facial procedures that involve setting of facial landmarks such as the lateral canthus, the nasal ala or earlobe position may also be subject to inverted viewing challenges. These types of procedures could benefit from upright viewing, whether by patient or surgeon positioning, when assessing resultant symmetry.

Visual perception frameworks for perceiving materials with complex appearances emphasise the power of supervised learning, using labelled data to improve perception and predict outcomes.[23] The randomisation in this experiment mitigated the effect of learning on the data as presented, however, it may be possible that specific inverted image recognition training may improve overall perception of asymmetry both during baseline evaluation and intraoperatively. Though even with routine training, it should be noted that inverted tasks remain more challenging. This is demonstrated by the fact that even experienced oculoplastic surgeons, with previous extensive intraoperative and clinical training in multiple positions and rotations of gaze, performed significantly worse with rotation away from upright in this study just as laypeople did. Interestingly, studies have shown that 3D faces are recognised more accurately and faster than two-dimensional (2D) faces in the upright position but have similar face inversion effects.[24] Therefore, even 2D image-based training on images at different degree of rotation may have implications for perception in 3D space. Future studies may explore the impact of training surgeons on perception of peak and ptosis in 2D images at different degrees of rotation on perception in 3D space.

This study is not without limitations. While MTurk allows for access to a large population of laypeople, the population is still less diverse than the general US population (eg, more highly educated and younger compared with the US population).[25] In addition, this study focused on a unilateral eyelid pathology although patients commonly present with different types and severities of asymmetry. Intraoperatively, this could pose a greater challenge. Future studies would benefit from exploring the difference in accuracy and RT of patients with bilateral asymmetry with differing type and severity for each eye at different degrees of rotation. In addition, this study assesses perception of asymmetry for 2D images, however, the relationships noted may differ in 3D when evaluating patients in person.[24] It is also important to note that this study considers perception of static asymmetry, however, this is not a direct proxy for effective management of asymmetry intraoperatively or differences in overall treatment success. Finally, this study did not quantify any operating room or clinical outcome findings and thus cannot be directly applied to a specific physical environment or task. Further studies trialling a mirror reversal apparatus in the operating room are ongoing.

Overall, this study highlights the challenges involved in the recognition of particularly small eyelid asymmetries under different rotational viewing conditions, demonstrating the significant inversion disability faced by oculoplastic surgeons. This study quantifies the extent to which inversion disability decreases accuracy in perception of asymmetries, even among experts with extensive training and experience. Understanding the extent of such limitations and considering how to improve them is integral to achieving optimal aesthetic and functional results. Beyond the implications for our understanding of visual processing of facial structures at different orientation in space, these findings may have practical implications for the assessment of patients under different viewing conditions, particularly in the inverted position as is common in various facial plastic surgeries performed at the head of the bed.

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