Reducing the risks of endoscopic sino-nasal surgery in the Covid-19 era

Running title: Reducing risks during sinus surgery

[1,2] Samuel C Leong MPhil FRCSEd(ORL-HNS), [3] Dilesh Mogre MS MRCS(ENT), [4] Peter Andrews BSc(Hons) MD FRCS(ORL-HNS), [5] Elgan Davies FRCS

[1] Department of Clinical Sciences, Liverpool School of Tropical Medicine, United Kingdom

[2] Liverpool Head and Neck Centre, Aintree University Hospital, Liverpool University Hospitals NHS Foundation Trust, United Kingdom

[3] Department of Otorhinolaryngology-Head and Neck Surgery, Wirral University Teaching Hospital NHS Foundation Trust, United Kingdom

[4] Department of Otorhinolaryngology-Head and Neck Surgery, University College London Hospitals NHS Foundation Trust, United Kingdom

[5] Spire Regency Hospital, Macclesfield, United Kingdom

Correspondence:

Mr. Samuel C Leong MPhil FRCSEd(ORL-HNS)

Lead Consultant, Liverpool Rhinology Fellowship

Aintree University Hospital

Liverpool University Hospitals NHS Foundation Trust

Liverpool L9 7AL, United Kingdom

Email: LCHEEL@doctors.org.uk

Fax: +44 151 529 5263

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MR SAMUEL C LEONG (Orcid ID : 0000-0002-7213-0387)
DR DILESH MOGRE (Orcid ID : 0000-0001-5434-1917)

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Reducing the risks of endoscopic sino-nasal surgery in the Covid-19 era

Running title: Reducing risks during sinus surgery

Key points:

- Endoscopic sinus surgery is an aerosol generating procedure (AGP).
- Understanding the relationship between irrigation rates and suction pressures when using the microdebrider can provide strategies to reduce the aerosolisation potential of powered sinus surgery.
- Activation of the microdebrider when there is fluid accumulation in the nasal cavity has been demonstrated to cause droplet contamination.
- Drilling with either coarse diamond or cutting burr resulted in detectable droplets. Greater droplet spread was observed when drilling within the anterior nasal cavity. The addition of a suction catheter reduces droplet spread when drilling.
- High-speed drilling is a high-risk AGP but the addition of suction reduces detectable droplet contamination outside the nasal cavity.

Abstract

Objectives: Many powered instruments used in routine sinonasal surgery are regarded as an aerosol generating procedure (AGP). This study aimed to assess assess how different instrument settings may affect detectable droplet spread and the patterns of aerosolised droplet spread during simulated sinonasal surgery with powered instrumentation in order to identify mitigation strategies.

Design: Simulation series using three-dimensional (3D) printed sinonasal model. Fluorescein droplet spread was assessed following microdebriding and drilling of fluorescein-soaked grapes and bones respectively.

Setting: University dry lab.

Participants: 3-D printed sinonasal model.

Main outcome measures: Patterns of aerosolised droplet spread.

Results and Conclusion: There were no observable fluorescein droplets or splatter in the measured surgical field after microdebridement of nasal polyps at a specific irrigation rate and suction pressure. Droplet splatter occurred when suction pressure was reduced; simulating a surgical condition where there was excessive fluid in the nasal cavity irrigation. Drilling with either coarse diamond or cutting burr resulted in detectable droplets. Greater droplet spread was observed when drilling within the anterior nasal cavity. The addition of a suction catheter reduces droplet spread when drilling. Activation of the microdebrider when there is fluid excess fluid (reduced or blocked suction pressure, excessive mucosal bleeding or irrigation fluid) accumulating in the nasal cavity resulted in detectable droplet spread. High-speed drilling is a high-risk AGP especially when drilling in the anterior nasal cavity, but the addition of suction reduces detectable droplet spread outside the nasal cavity.

Key words: COVID-19, aerosol-generating Procedure, nasal endoscopy, sinus surgery, skull base surgery, droplet

Level of Evidence: 5

Conflict of interest: none

Introduction

High risk of transmission of respiratory viruses occurs during aerosol generating procedures (AGPs) of the respiratory tract. Powered instruments typically used during ENT procedures, such as intranasal microdebriding or mastoid drilling, have been identified as AGPs although the actual risk of transmitting viral particles remain uncertain[1]. Prior to the Covid-19 pandemic and subsequent reported deaths of surgeons contracting coronavirus from infected patients, the risk of aerosolised transmission was recognised but not considered to be as dangerous. This realisation resulted in temporary cessation of elective surgery, including all routine ENT procedures[2,3]. The current recommendations for personal protective equipment (PPE) required to undertake AGPs continue to evolve as new epidemiologic and scientific evidence become available, influenced by external factors such as socio-economic pressures including supply chain issues and advice from medical professional associations. Recent studies, prompted by the Coid-19 pandemic, have objectively demonstrated that many powered instruments used in sinonasal surgery are aerosol generating with high speed drilling resulting in the greatest AGP potential[4,5,6,7].

While previous studies have described the patterns of aerosolised droplet spread during simulated endoscopic sinonasal surgery, the aim of this study was to assess how different instrument settings may affect detectable droplet spread. The ability to vary instrument settings mimics real-life conditions where surgeons may have personal preferences or may choose to alter the settings to better suit the clinicopathological requirement. It is envisaged that the results of this study would better inform on how best to mitigate droplet spread, evaluate choice of instruments and whether droplet spread is site dependent within the sino-nasal cavity.

Methods

Ethical considerations

The study protocol was approved by the Research Governance and Ethics Office of the Liverpool School of Tropical Medicine (Research Protocol 20-046).

Experimental set up

All simulated surgical procedures were undertaken in the dry laboratory on a realistic, life-sized model (3D LifePrints, Liverpool, U.K) derived from open-sourced CT scan data (OsiriX. Pixmeo SARL, Geneva, Switzerland). The 3-D printed model was placed in a supine, 30° head-up position on a medical examination bench covered by an impervious black sheet (Figure 1a,b). A grid pattern on the sheet followed the design described in a recently published study4. The model was placed at the apex of a triangle extending to the edges of the sheet at a 50° angle, with the sides of the triangle extending from the model measuring 55cm to the edge of the sheet. Subdivisions were made, with the central portion of the first subdivisions positioned 6cm away from the nasal aperture, and each subsequent subdivision at 12-cm intervals. Sections closer to the nares were divided into smaller subdivisions. Each subdivision was at least 10cm in maximum diameter.

Simulated surgical procedures

The procedures include:

1. External activation of microdebrider and blade outside nasal cavity,
2. intranasal microdebridement of nasal polyps,
3. high-speed drilling of bone.

Microdebrider simulations were carried out using the Straightshot™ M5 handpiece (Medtronic Inc., Jacksonville, FL, USA) and 4mm TriCut® blade. Fluorescein was added to the irrigation fluid; 1g dye diluted in 250mL irrigation fluid. Various irrigation rates,

oscillation speeds and suction pressure settings were tested (Table 1). With each combination of settings, the microdebrider was activated for one minute and the presence of fluorescein-dyed irrigation fluid drips and droplets from the instrument tip (Figure 1b) were assessed in the darkened laboratory room aided by a UV lamp.

Peeled grapes soaked overnight in diluted fluorescein dye solution (1mg in 25mL) were used to simulate nasal polyps. Simulated endonasal surgery was performed with the aid of a 4mm 0° endoscope connected to a monitor and camera system (Karl Storz, Tuttlingen, Germany). At the start of each experiment, pieces of grape were placed in the nasal cavity and middle meatus of the model before microdebriding for one minute (Figure 1c). The black sheet was then inspected for fluorescein droplets using the UV lamp (Figure 1d,e).

For surgical drilling simulation, 1cm x 1cm blocks of sterilised porcine rib soaked in fluorescein dye solution (1mg in 25mL) were used. One piece of bone was placed on the face of sphenoid adjacent to the nasal septum to simulate drilling of the sphenoid rostrum. A second piece was tucked under the inferior turbinate to simulate drilling in the anterior nasal cavity (e.g. lateral nasal wall during medial maxillectomy). Drilling was undertaken with either a 5mm 15° curved coarse diamond burr or a 4mm 15° curved cutting burr with an activation period of one minute. The diamond burr was attached to the Straightshot™ M5 handpiece while the cutting burr was attached to the Midas Rex Legend Stylus. The fluorescein droplet assessment and surgical field cleaning process followed each experiment, and this was repeated four times to provide five sets of data. To simulate the two surgeon, three-hand technique an additional suction (Storz 3mm Frazier suction tube) was introduced and placed within the surgical field to remove excess irrigation fluid.

Quantification of fluorescein droplets and reporting of data

The assessment of dripping from the instrument tip during external activation of the microdebrider was undertaken in binary fashion i.e. present or not present (Figure 1b). Similarly, the presence of droplet deposition on the surgical field following intranasal activation of the microdebrider or drill was determined in a binary fashion (Figure 1d,e). As each experiment had a total of five data sets, the results were aggregated into a heatmap to

illustrate the frequency of droplet detection; 0 = black, 1-2 = yellow, 3-4 = orange and 5 = red.

Results

During external activation of the microdebrider at 2000rpm (oscillation mode), dripping from the instrument tip occurred as the irrigation rate was increased incrementally while suction pressure was fixed (Table 1). Higher irrigation rates required higher suction pressures to stop dripping from occurring. Expectantly, dripping from the microdebrider tip occurred when suction was switched off and when the irrigation rate was increased to 40ml/min despite having maximum suction pressure (240mmHg). When the irrigation rate fixed at 25ml/min, no dripping was observed during oscillation at 5000rpm with suction pressure set at 140mmHg and above. When the microdebrider was switched to forward mode (e.g. to simulate shaving turbinate bone during turbinoplasty) with 25ml/min irrigation maintained, no dripping was observed at all suction pressure settings. However, at 40ml/min irrigation dripping was observed even at the highest suction pressure setting.

Extra-nasal microdebriding of fluorescein soaked grapes resulted in droplets on the detection grid (Figure 2a). When microdebriding the simulated nasal polyps within the nasal cavity, no fluorescein droplets were detected at a constant microdebrider setting of 2000rpm oscillation (irrigation 25ml/min, suction pressure 200mmHg), (Figure 2b). In contrast, droplets were detected on the grid area adjacent to the nares when suction pressure was reduced to 100mmHg (Figure 2c).

Although diamond and cutting burrs have built-in irrigation, only the former has a suction evacuation port. Drilling with the cutting burr resulted in greater and wider spread of droplets on the detection grid than with the diamond burr (Figure 3a,b,c,d,e,f and 4a,b,c,d). Regardless of burr type, drilling on the sphenoid rostrum resulted in less droplet detection compared to drilling within the anterior nasal cavity. The introduction of an additional suction tube resulted in no droplet detected on the grid when the sphenoid rostrum was drilled with the diamond burr (Figure 3f).

Discussion

Synopsis of key/new findings

The paradigm shift in sinus surgery was driven by the introduction of the endoscope in the 1980s and in the following decade, adoption of powered instruments in routine clinical practice[8,9,]. The microdebrider, a ubiquitous tool in modern endoscopic sinus surgery, was adapted from powered instruments commonly used in orthopaedic surgery at the time[10]. Despite modifications and improvements to the microdebrider, the principles and mechanics that govern its basic functionality have stood the test of time. Adequate suction pressure is required to draw soft tissue into the rotating microdebrider blade with enough irrigation flowing through the instrument to effect removal of exenterated tissue and equally critical, to prevent clogging of the instrument. These variables are also influenced by the speed of the rotating or oscillating microdebrider blade; the higher the revolutions, there is less time the instrument tip is in the open configuration for soft tissue to be drawn into the cutting surface thus reducing the efficiency of the blade.

At an oscillating rate of 2,000rpm, the optimum point appears to be at 25ml/min irrigation and 200mmHg suction pressure. At this setting, no dripping outside the nasal cavity (Table 1) and no detectable droplets were observed when nasal polyps were debrided (Figure 2b) although droplets were detected when the suction pressure was reduced to 100mmHg (Figure 2c). The latter observation may infer that greater aerosolisation of intranasal fluid occurs when the microdebrider is blocked or when there is excessive fluid in the operative field. Excessive bleeding from sinonasal mucosa would also increase the volume of fluid within the nasal cavity potentially resulting greater aerosolisation during surgery.

High speed drilling within the nasal cavity, regardless of revolution speed or burr type (diamond versus cutting) results in detectable droplet spread outside the nasal cavity (Figure 3b,e and Figure 4a,c) which corroborated with observations reported by other groups[7,13]. The addition of suction, whether it is a built-in feature of the burr or provided by the introduction of an additional suction catheter, does not eliminate extranasal droplet spread. In addition, drilling in the anterior part of the nasal cavity resulted in greater droplet spread outside the nasal cavity than drilling more posteriorly (Figure 3b,e and Figure 4c,d). Although not

simulated in our study, drilling of the frontal beak also resulted in detectable splatter contamination up to 9cm away from the nasal cavity [5].

Strengths of the study

Unlike recent studies where cadavers were utilized in the experiments, we decided to use a realistic 3-D printed model because we wanted to simulate common sinonasal procedures such as nasal polypectomy and, be able to replicate the experiments consistently and observe for trends in the results. We also believed that fluorescein-soaked grapes were better than fluorescein-stained mucosa as there was greater soft tissue volume for microdebriding. During the set-up phase of our study, we concluded that 2.5mL of diluted fluorescein (as reported in the Workman et al. study) was insufficient volume to completely saturate the nasal cavity which led us to add fluorescein into the irrigation fluid. We also evaluated the technique described by another research group of filling the sinus and nasal cavity with 1 mg/mL fluorescein solution to the level of the anterior head of the inferior turbinate for 15 minutes, but realised that it was more effective soaking the simulated tissue (grapes, bone) in fluorescein[5]. We activated the powered instruments for a continuous period of one minute while other studies were described microdebriding for 10 minutes and drilling for 5 minutes. We believed that the ability to replace and reposition the simulated nasal polyps and bone represented a better method of replicating each experimental condition.

Comparisons with other studies

This study has focused on instruments designed by one manufacturer (Medtronic Inc., Jacksonville, USA) and therefore should not be extrapolated to other makes of microdebrider or drills. The study reported by Sharma et al. utilised the Entellus Medical Shaver System SS-100 microdebrider (Stryker Inc., Kalamazoo, MI, USA) set at 5,000 rpm [4]. The authors simulated endoscopic sinus surgery on cadavers and after 10 minutes of using the microdebrider, droplets were observed up to 6 cm away from the nasal cavity. Both irrigation rate and suction pressure was not specified in their paper, and it is unclear if blockage of the microdebrider occurred during the 10 minutes of simulated surgery. In our study, microdebriding or drilling was limited to one minute. While we recognize that this does not necessarily reflect real-life conditions or practices, surgeons are unlikely to have the microdebrider or drill activated for an extended period of several minutes continuously.

The addition of a suction catheter when drilling the sphenoid rostrum resulted in no detectable splatter droplets (Figure 3f). The coarse diamond burr used in our experiment has a built-in suction port at the tip of the round burr and that endonasal drilling should be performed using the sides of the burr instead of the tip. The study reported by Dharmajan et al. also concluded that the placement of an additional suction in the nasal cavity or nasopharynx during drilling resulted in complete elimination of all detectable aerosols by a high-fidelity particle counter[11]. It is important to note however, that the risk of AGP remains and in no way obviates the need for appropriate PPE.

Limitations of this study

The experiments were undertaken on a life-sized 3-D printed model based on an adult normal CT scan. The model lacked hair around the nasal vestibule which if present may reduce the amount of splatter droplet detected. In addition, anatomical variations such as septal deviation, hypertrophic inferior turbinate or concha bullosa may affect the platter patterns but this was not evaluated in our study nor was it considered in previous AGP-related studies on human cadavers[4,5,6,7]. Grapes and porcine rib do not mimic nasal polyps or sinonasal bone respectively. This may also affect the splatter patterns due to the different tissue composition and how tissue particulates are formed from the action of the microdebrider or drill. Nevertheless, we decided to use these human tissue substitutes because the human anatomy laboratory was closed during the U.K. national lockdown and given the limited number of available cadavers, we would not have been able to replicate the large number of experiments in the study protocol.

The ability to detect splatter on the detection grid corroborates with previous studies that microdebriding and drilling are AGPs. The presence of airborne particulates was not assessed because we did not have an optical particle counter. The study reported by Workman et al[13] noted that there were more airborne particles when dry drilling the anterior part of the nasal cavity. When suction was added during intra-nasal drilling, significant 1-10μm airborne particulate generation over baseline concentrations was not observed in either posterior or anterior drilling conditions. Given that our study lacked the sophisticated droplet detection methods described in other reports, it is highly plausible that the droplet patterns are either more intense or more widespread than what has been observed. The technique described by

Workman et al. had an estimated size detection limit of 20μm, although the inertial impaction method described by Dharmarajan et al. could detect particles <15 μm in diameter[4,11]. The latter study noted that the placement of a suction instrument in the nasal cavity or nasopharynx led to complete elimination of all detectable aerosols.

Clinical applicability of the study

The aim of the present study has not been to eliminate the AGP potential of powered instruments, but rather to provide greater understanding of an issue poorly understood prior to the Covid-19 pandemic and to offer mitigation strategies to optimise safer surgical environment. Surgeons undertaking endoscopic sinus surgery should be aware of the technical parameters of the various powered instruments they use, as well as being able to alter settings and troubleshoot when necessary. Activation of the microdebrider or drill burr should not occur outside the nasal cavity, especially after the instrument has been used in the patient.

A clear understanding of the interactions between irrigation rates and suction pressures when using the microdebrider or drill provides an additional intervention to minimise the aerosolisation potential of sinonasal surgery. It should be noted that the data presented in this study has focused on instruments manufactured by one company (Medtronic Inc., Jacksonville, USA) and therefore should not be extrapolated to other types of hand-held microdebrider or drills. This is because burr designs and instrument performance settings differ across the various manufacturers. The placement of an additional suction catheter during endonasal drilling, either held by an assistant (three-hand technique) or placed in the vicinity of the surgical field, reduces droplet spread[4,12, 13].

Conclusion

Understanding the relationship between irrigation rates and suction pressures when using the microdebrider can provide strategies to reduce the aerosolisation potential of powered sinus surgery. Activation of the microdebrider when there is fluid accumulation in the nasal cavity has been demonstrated to cause droplet contamination. High-speed drilling is a high-risk AGP, but the addition of suction reduces detectable droplet contamination outside the nasal cavity.

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Legend to tables and figures

Table 1. Assessment of fluorescein-dyed irrigation dripping from the microdebrider tip during external activation for one minute. Present = Yes, not present = No. N/A = not applicable. *There is no integrated suction port in the Midas Rex Legend Stylus drill handpiece.

Figure 1. Experimental setup: (a) Model of the head draped with grid detection sheet. Inset shows close-up of the 3-D printed nose and paranasal cavity. (b) Example of dripping from microdebrider after activation. (c) Endoscopic view of fluorescein stained grapes mimicking nasal polyps. (d) and (e) Example of droplets identified on detection grip before and after UV lamp illumination.

Figure 2. Illustration of geographic spread of aerosol droplets by 4mm TriCut® blade: (a) extranasal microdebridement (2000rpm oscillation, irrigation 25ml/min, suction pressure 200mmHg) of simulated nasal polyp, (b) intranasal microdebridement (2000rpm oscillation, irrigation 25ml/min, suction pressure 200mmHg) of simulated nasal polyp and (c) extranasal

microdebridement (2000rpm oscillation, irrigation 25ml/min, suction pressure 100mmHg) of simulated nasal polyp.

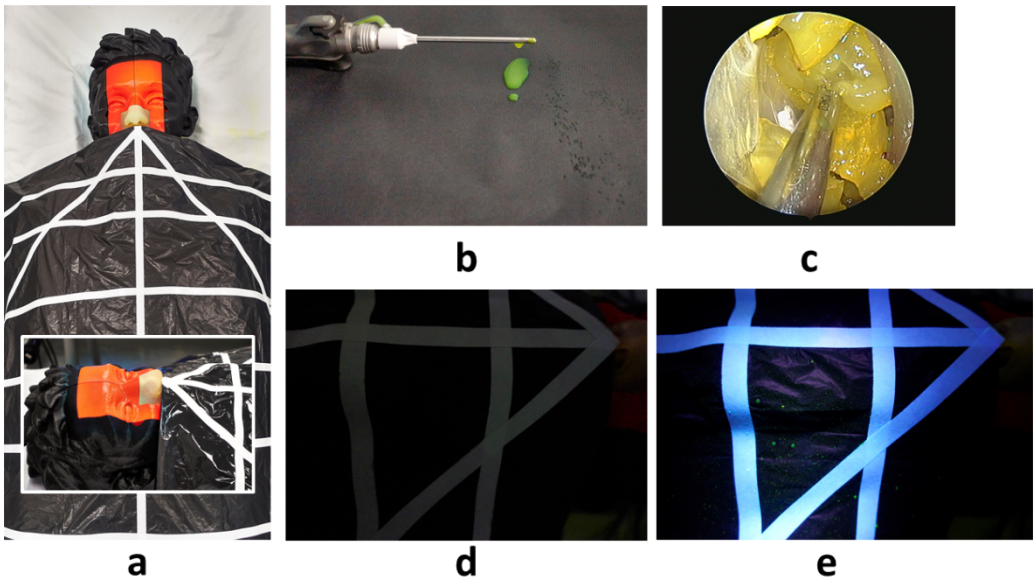
Figure 3. Illustration of geographic spread of aerosol droplets caused by 5mm 15° curved diamond burr (12,000 rpm) when drilling in the anterior nasal cavity (a,b,c) and on the sphenoid rostrum (d,e,f). Built-in suction switched off = a,d. Built-in suction switched on = b,e. Additional Frazer suction = c,f.

Figure 4. Illustration of geographic spread of aerosol droplets caused by 4mm 15° curved cutting burr (60,000 rpm) when drilling in the anterior nasal cavity (a,b) and on the sphenoid rostrum (c,d). No suction = a,c. Additional Frazer suction = b,d

Handpiece type and setting	Irrigation rate (ml/min)	Suction pressure (mmHg)						
		0 (suction off)	100	140	180	200	220	240
Microdebrider. Oscillation mode, 2000 rpm	5	Yes	No	No	No	No	No	No
	15	Yes	No	No	No	No	No	No
	20	Yes	No	No	No	No	No	No
	25	Yes	Yes	Yes	Yes	No	No	No
	30	Yes	Yes	Yes	Yes	Yes	Yes	No
	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Microdebrider. Oscillation mode, 5000 rpm	25	Yes	Yes	No	No	No	No	No
Microdebrider. Forward mode, 6000 rpm	25	Yes	No	No	No	No	No	No
	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes
High-speed drill, Diamond burr, 12000 rpm	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes

High-speed drill. Cutting burr, 60000 rpm	20	Yes*	N/A

Table 1. Assessment of fluorescein-dyed irrigation dripping from the microdebrider tip during external activation for one minute. Present = Yes, not present = No. N/A = not applicable. *There is no integrated suction port in the Midas Rex Legend Stylus drill handpiece.



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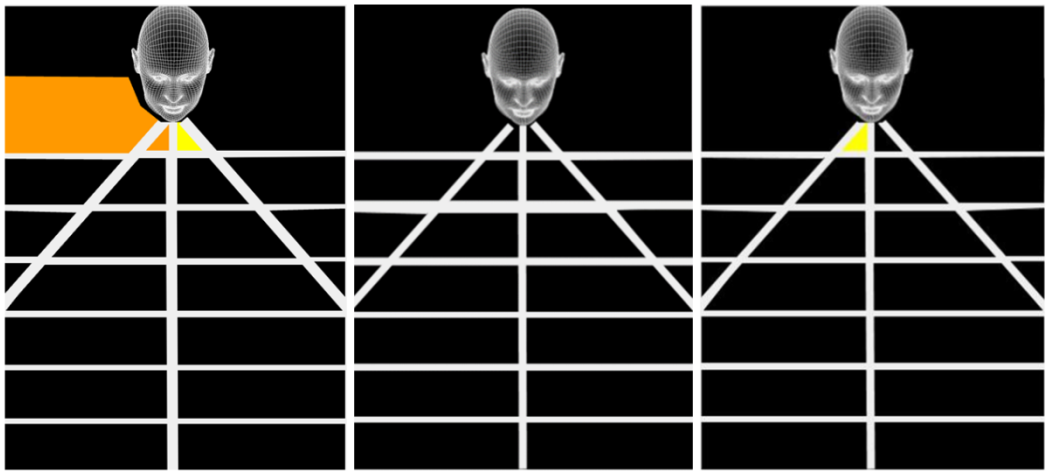

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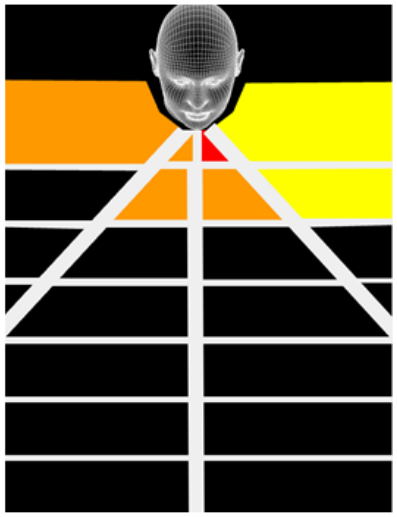

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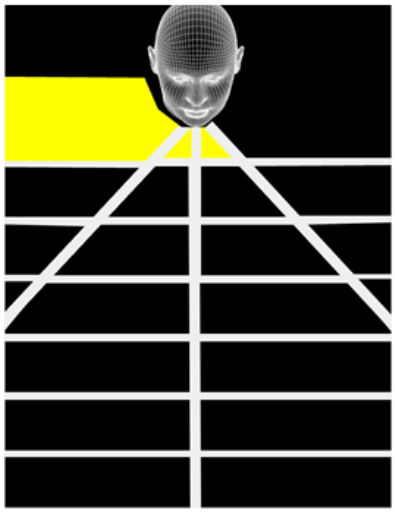

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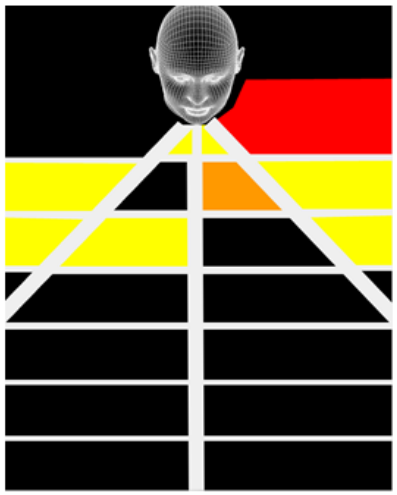

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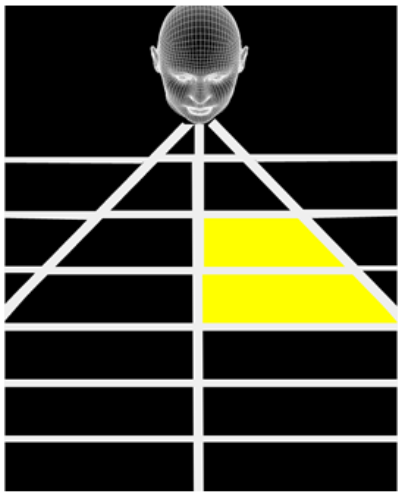

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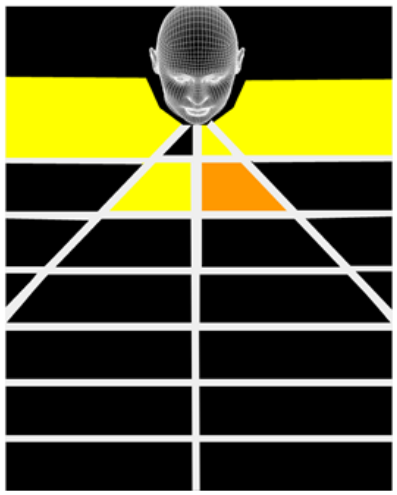

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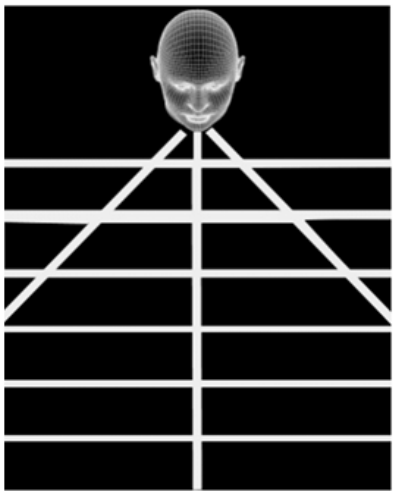

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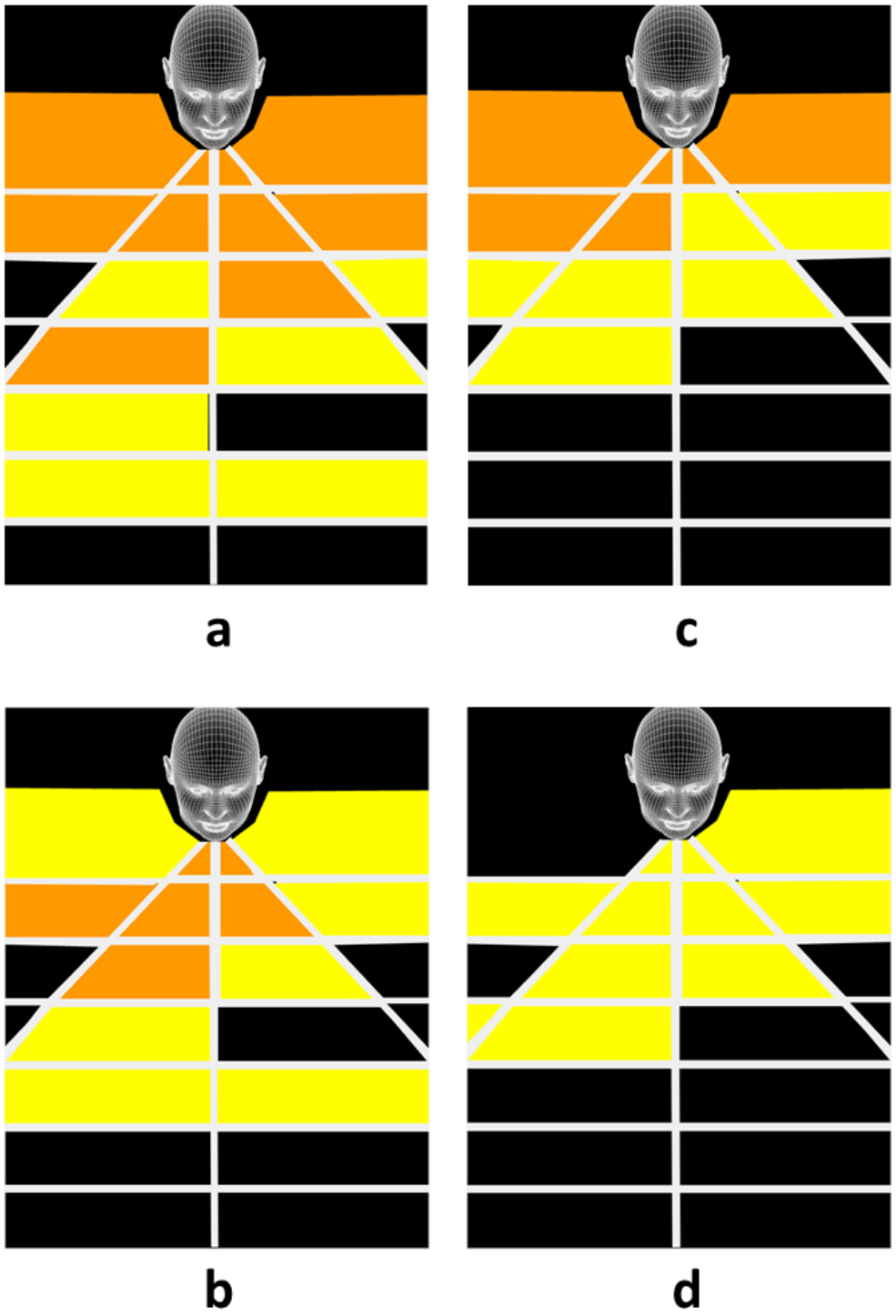

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