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Daniel J. Graham

To cite this article: Daniel J. Graham (12 Jan 2024): Purple Perils redux: Open-ended, AI-resistant reasoning problems for introductory undergraduate sensation and perception instruction, Visual Cognition, DOI: [10.1080/13506285.2023.2250518](https://doi.org/10.1080/13506285.2023.2250518)

To link to this article: <https://doi.org/10.1080/13506285.2023.2250518>



Published online: 12 Jan 2024.



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Purple Perils redux: Open-ended, AI-resistant reasoning problems for introductory undergraduate sensation and perception instruction

Daniel J. Graham

Department of Psychological Science, Hobart & William Smith Colleges, Geneva, NY, USA

ABSTRACT

In terms of pedagogy, there is a need in introductory sensation and perception courses for practice problems that promote critical thinking and elaborate on course material, like those given in the physical sciences. However, perceptual psychology mostly lacks the mathematical foundations that provide ready material for such elaborative assignments. Here I introduce a series of short assignments dubbed Purple Perils, which are inspired by the perception-related missives made famous by J. J. Gibson. These assignments provide students with open-ended opportunities to think through compelling and relatable problems in perception, often with an applied component. By their nature, such assignments are at present somewhat resistant to large language model AI assistance: probes of ChatGPT suggest that students who illicitly use such systems may not gain the synthesis of ideas that Purple Perils demand, and will therefore be disincentivized to use such illicit aid. This kind of assignment can reinforce learning in topics across sensory modalities, and can be used for exam questions. Purple Perils promote critical thinking and quantitative reasoning, e.g., through graphical literacy; reinforce biological knowledge; encourage classroom debate and discussion; and connect to historical and contemporary debates and findings. Gibson's own Purple Peril about the El Greco fallacy leads the series of assignments. A protected, crowd-sourced, repository of Purple Perils is also deployed to allow sharing of questions among instructors.

ARTICLE HISTORY

Received 8 February 2023
Accepted 10 August 2023

KEYWORDS

Perception; pedagogy; ecological vision; reasoning; large language models; undergraduate education; artificial intelligence

The great theorist of human perception, J. J. Gibson – whose influence still permeates perceptual psychology, visual neuroscience, neurophilosophy, and numerous other fields – was famous both at his home institution of Cornell University and beyond for what came to be known as “Purple Perils.” Gibson wrote these short missives, which got their name because they were printed in purple ink on mimeograph machines, during the 1960s and 70s in advance of psychology department seminars and visits by leading researchers from other institutions. Gibson's goal was to stimulate debate about fundamental issues in perceptual psychology by meditating on curious or seemingly paradoxical phenomena of perception, often in an applied setting. In accordance with Gibson's ecological viewpoint, Purple Perils often revealed or invoked the complexities and regularities of the physical environment in examining how they shape perception.

Above all, Gibson's Purple Perils embodied a spirit of critical thinking, creativity, and exploration in

sensation and perception. The questions he posed can serve as a model of how to reason about sensation and perception for students beginning their study of the field.

Here I describe a new set of Purple Peril questions inspired by Gibson that provides students with open-ended opportunities to think through compelling puzzles in perception, usually with an applied component. These questions have fairly straightforward solutions (or sets of solutions), meaning that an objective standard can be applied to evaluating student performance in synthesizing learned material. As such, they form a kind of parallel to problem set assignments found in undergraduate physical and mathematical science courses. Each Purple Peril exercise requires only relatively brief responses, but each also requires focused thought.

The exercises reinforce course material across modalities and connect to current issues and debates in perception research. At the same time, these assignments provide a link to the history of perceptual

psychology, especially its theoretical and applied dimensions. Because the best answers to these questions often involve making a turn of logic or perspective, or having a flash of insight, they make excellent fodder for class discussion, with students typically eager to share their reasoning with classmates. The questions can also be used in exams as probes of synthetic thinking.

Purple Peril assignments are intended to be relatively resistant to student use of unauthorized assistance from artificial intelligence (AI). I will show circumstantial evidence that the logical, applied, and/or creative demands of these questions may discourage this method of cheating.

Purple peril assignments: examples

The El Greco fallacy

Gibson's own 1972 Purple Peril regarding the El Greco fallacy leads the series. It can be assigned early in the course since it requires relatively little technical knowledge.

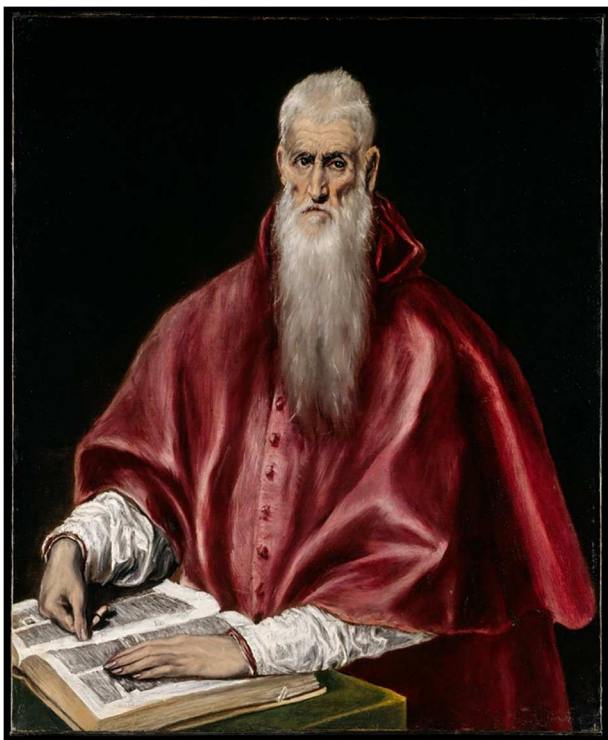


Figure 1. El Greco (Doménikos Theotokópoulos) (1541–1614), Saint Jerome as Scholar, c. 1610.

Source: Wikimedia Commons, public domain.

In regard to the origins of El Greco's distinctive style, Gibson sketched a hypothesis that has a history stretching back to the early twentieth century (Firestone, 2013). Gibson wrote:

In explanation of the fact that El Greco painted saints as elongated in height (and supposedly even ordinary persons and objects) it has been suggested that he suffered from astigmatism which caused his retinal images to be vertically narrower than they should be. Therefore, his perceptions of persons and things were elongated, that is, he saw things thinner than they really were, and this explains why his paintings of persons and things were elongated. (emphasis Gibson's; courtesy of Bill Mace's online collection of Gibson's Purple Perils: <https://commons.trincoll.edu/purpleperils/>)

Gibson goes on to show why this logic is fallacious. At its heart, the explanation turns on the fact that the painter observes both the to-be-painted object (e.g., a face), and the canvas on which the painting is made, with the same eyes. Therefore, if an observed face is "felt" as elongated, putatively due to astigmatism, then the painted face will also "feel" elongated to the artist, assuming the artist maps visual space accurately as they perceive it. To a non-astigmatic observer, both the observed face and the painted face will thus appear normal, i.e., not elongated. Any putative affine transform will behave this way since no information in the observed image is lost in the painting.¹

Many different phrasings of the question are possible but in presenting this question to undergraduates, I have used the following formulation (Figure 1):

Instructions: Write a few paragraphs addressing each question below. You may use your textbook and class notes but not outside resources. (NOTE: outside resources are in any case a bad idea with Purple Perils because websites and chatbots may give incorrect answers to these questions)

The great Spanish painter El Greco (1541–1614) was famous for depicting human forms that are quite elongated in the vertical direction. Art historians have speculated that this may have resulted from astigmatism in the artist's eyes. Is the astigmatism hypothesis reasonable? Why or why not?

A hint can also be given along the lines of: "Consider the perceptual situation of artists painting the world around them and the possible effects of visual distortions on their art," or "think about the effects of astigmatism and how objects are depicted in paintings."

Anecdotally, in every section of Sensation and Perception taught by the author over ten years at a small undergraduate liberal arts institution, including online instantiations, at least one student has been able to describe, with some demonstrable intellectual satisfaction, the source of the logical fallacy to classmates. Many other students, while not fully explicating the logical fallacy, successfully make other observations that cast doubt on the hypothesis. For example, they may note that human faces and bodies are elongated but other objects are either not elongated, or elongated in different orientations. A further line of argument students often make is that astigmatism causes blurring in the retinal image, rather than stretching or elongation.

In assessing student responses, I look for some recognition of an inconsistency of logic in the hypothesis, as in the arguments above, in awarding highest marks. Responses that note only that artists make many stylistic choices, which don't necessarily relate to visual deficits, without examining the logical fallacy, receive partial credit. Responses that blindly accept the hypothesis receive no credit. This Purple Peril serves as a launching point for discussions of current issues in perception. For example, it relates to the search for "top-down" influences on perception (see Firestone & Scholl, 2014).

This question appears relatively resistant to the use of AI systems for unauthorized assistance. When asked "Was El Greco astigmatic?" in January, 2023, ChatGPT (version 0.9.2) responded:

It is not clear whether El Greco (Domenikos Theotokopoulos) was astigmatic or not. Astigmatism is a common eye condition that affects the way the eye focuses light, and it can cause distorted or blurred vision. There is no historical documentation or records that indicate whether El Greco had this condition or not. It has been speculated that El Greco's elongated figures and distorted forms in his paintings may have been a stylistic choice, rather than a result of an astigmatic vision, as his ability to depict the human form with such detail and accuracy suggests that he had strong visual acuity. It is also possible that El Greco could have been affected by other visual disorders which could have influenced his artistic style. However, this is not confirmed and remains a subject of debate among art historians and scholars.²

According to the rubric above, this response would receive at best partial credit since it does not identify or explain the central fallacy, nor does it cite specific evidence that casts doubt on the hypothesis.

Nightlights

A second Purple Peril devised by the author probes a relatable and practical problem: what is the best spectral colour for a nightlight given human photoreceptor absorbances? The question can be posed as follows (Figure 2):

Imagine you have been tasked with designing a nightlight for General Electric (GE). Nightlights provide quite low levels of illumination, so this is an important design requirement. In addition, your supervisor would like the nightlight you design to still enable customers to have decent acuity for details and shapes when no other lights are on, but also to preserve night vision as much as possible. For example, you want people to be able to get from their bedroom to the bathroom and back safely in the middle of the night without turning on lights. Below is a figure showing the relative absorbance of the four photoreceptor types in humans.

Based on the absorption spectra, what color/wavelength of light would be the best choice for your nightlight? What colors/wavelengths would be a bad choice? Why?

To solve this Peril, students first need to make sense of the absorption spectrum plot. Having learned in the course that rod photoreceptor activity dominates at low light levels, some students look for the peak of absorption for rods, 420 nm, and conclude that blue is the best colour. This may concur with experience. Though many colours are available from online sellers, blue nightlights are common: blue is the only colour of nightlight sold at the grocery store adjacent to the author's campus, for example.

However, the majority of students are able to work out from the plot that colours such as red that stimulate rods *least* are in fact most desirable. Given the ubiquity of "Night Shift" and other daylight-linked screen colour adjustments in students' lives, some also make the connection and argue that blue should be avoided. This response naturally opens discussion of the discovery of melanopsin and its spectral sensitivity, and intrinsically photo-sensitive retinal ganglion cells and their connection to circadian rhythms and other brain systems (see, e.g., Do, 2019). This latter point can be cleaved from the practical visual requirements of the question. In support of their argument, students may also observe that deliberately dark environments such as photographic

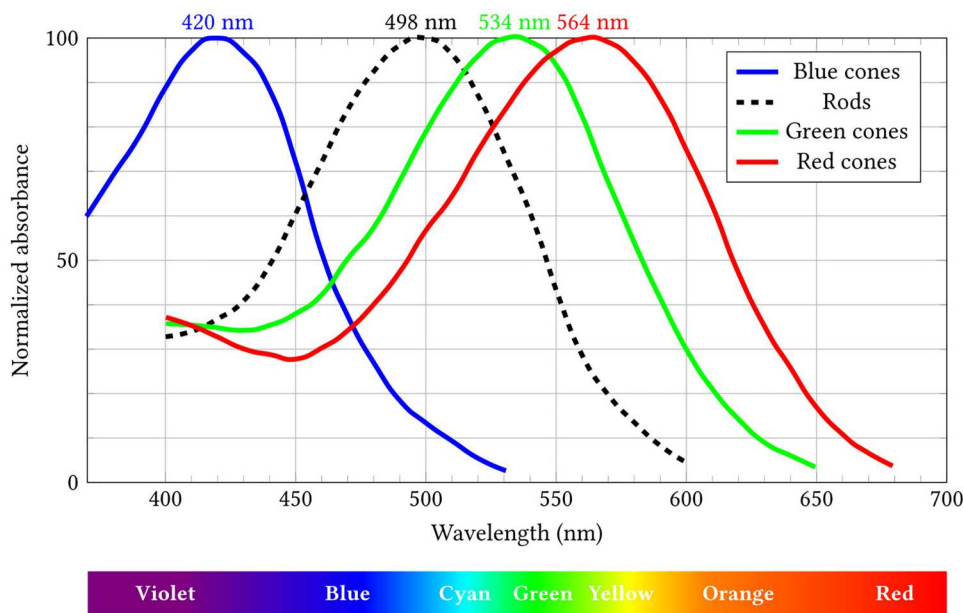


Figure 2. Photoreceptor absorption spectra.

Source: Wikipedia/Francois~frwiki, CC BY-SA 4.0.

darkrooms and astronomical observatories often have red lights to assist with visibility. Overall, the author's experience is that students largely make cogent arguments as to why a red nightlight would be best at preserving night vision while allowing navigation in a dark room.³ This Peril can be supplemented with in-class demonstration or at-home experimentation with nightlights of different colours. A discussion of night vision prompted by this exercise can be extended with other demonstrations, such as the striking "droopy eyelid" illusion (Wolfe & Ali, 2015).

When asked, "What is the best color for a nightlight?" ChatGPT responded:

The best color for a nightlight depends on personal preference and the intended purpose of the nightlight. Some people prefer a warm and soft yellow color that mimics candlelight and creates a calming and relaxing atmosphere in the room. Others might prefer a cool white light that provides enough illumination for midnight trips to the bathroom or for checking on a sleeping child. Some nightlights also come with adjustable color options, allowing you to choose the color that works best for you.

This again is a response that misses the basic vision-relevant arguments and would receive low marks. Other phrasings of the question produced similar results.

Brown-Séquard Syndrome

Purple Perils can be devised for modalities other than vision. One is the following:

Consider a patient, X, who has suffered a stab wound to the back during a fight. While X had his back turned to his assailant, the assailant stabbed X in the middle of the back, with the dagger's blade entering parallel to the spinal column, and striking slightly left of center in the spinal cord. MRI imaging later revealed that X's gray and white commissure had been bisected. What sorts of **sensory** deficits do you think X would experience?

In the author's experience, most students are able to recognize that the spinal cord hemisection described can result in Brown-Séquard Syndrome, wherein proprioception and fine touch are lost on the same (ipsilateral) side as the wound, while pain and temperature are lost on the opposite (contralateral) side, based on course material regarding dorsal column-medial lemniscal (DCML) and spinothalamic pathways.

Here again ChatGPT failed to mention the ipsi/contralateral differences, or the relevant pathways, which are the main target of the question:

The patient X is likely to experience sensory deficits in the lower extremities, such as decreased or loss of sensation, motor function, and possible muscle weakness

or paralysis, based on the location of the stab wound near the center of the spinal cord. The extent of the deficits would depend on the extent of the injury to the spinal cord.

This response would receive only partial credit. However, in formulating a question along these lines, it may be advisable for instructors to avoid terms such as Brown-Séquard Syndrome or spinal cord hemisection, which could tip off AI systems – or indeed illicit users of Google – to the desired response. Students should be encouraged to work out the correct solely based on the provided information.

Additional questions

Below are additional Perils, with solutions and AI responses. As can be seen, questions with jargon terms can be more easily solved by AI, presumably because the systems were trained on reference texts containing these terms and their explication.

- (a) Listen to the sound linked at this address: <http://people.hws.edu/graham/rising-tone-illusion.mp4>.⁴ As you will hear, the tones appear to be continuously ascending. This is an auditory illusion. Based on the spectrogram of this sound which is displayed in the linked video, propose an explanation of why this illusion works.
- (i) *Solution:* As can be seen in the spectrogram that accompanies the recording, tones are octaves apart, with lower octaves increasing in intensity as they ascend in pitch, then descending in intensity as they reach the highest pitches, creating a seamless and seemingly unending upward cycle. Because the combined sounds are made up of multiple octaves, they are ambiguous as to which octave they belong to. The reason that we hear the Shepard tones as increasing in pitch is because of proximity – if the first note is an A, the second a B, the brain will perceive that as ascending one step, rather than descending nearly a full octave.
- (ii) *ChatGPT response:*

The Shepard Tone is an auditory illusion where a rising or falling sound appears to be infinite. It's created by layering multiple notes, each an octave apart, with the highest and lowest notes looping back to the start.

The ear perceives a never-ending ascent or descent, but in reality, the notes repeat and create an illusion of a continuously ascending or descending pitch. This illusion has been used in various forms of media, including film and video games, to create tension or suspense.⁵

Comments: This response, though lacking a full explanation of the root of the illusion, captures the basic mechanics of the auditory illusion. Since the phenomenon of Shepard tones is well known and has a canonical jargon term, this Purple Peril appears to be a relatively easy task for AI to solve (and indeed a simple Google search would suffice). The question for students is therefore phrased in a way that avoids the term "Shepard tone."

- (a) *The CMYK system of printing is used throughout the publishing industry to produce color images in magazines, books, etc. CMYK is a system of mixing inks, whose letters stand for Cyan, Magenta, Yellow and black. In other words, CMYK systems lay down layers of yellow, cyan, magenta and black ink in succession to make a color image. Explain why the C, M and Y layers are necessary for printing full-color images, and why the K layer is in theory unnecessary. Why do you think the system has the unnecessary K layer?*
- (i) *Solution:* Through subtractive mixing, C, M, and Y can produce black, but using a K layer for black saves ink and therefore cost. Also, the cyan, magenta and yellow aren't perfect primaries, and their combination will result in a muddy brown, rather than a crisp black.
- (ii) *ChatGPT Response:*

The C, M, and Y (Cyan, Magenta, Yellow) layers are necessary for printing full-color images because they represent the subtractive primary colors, which can be mixed to produce a wide range of colors. When these colors are superimposed on top of one another in different combinations and intensities, they can produce a full-color image. The K (Black) layer is in theory unnecessary because it is possible to achieve a suitable level of darkness by printing the C, M, and Y layers at maximum density. However, the addition of a separate K layer can increase the print quality, as it provides a more accurate and consistent representation of black and dark tones. The K layer is included in the CMYK printing system because it can result in a more cost-effective and efficient printing process, as well as a higher quality output. Additionally, the K layer can

improve the contrast and detail in images, especially in areas of shading and shadow.⁶

Comments: This response well identifies the logic probed by the question.

(a) *Everyone has experienced pruney fingers and toes. This is what happens when you spend a long time in the water. Most people – including many scientists – have long assumed that the skin simply becomes waterlogged and it wrinkles naturally like a wet piece of cardboard. But people whose nerves connecting their hand and spinal cord have been severed do not show a wrinkle response to wetness. What might this mean in terms of the neural mechanisms of pruney-ness? Describe a potential neural pathway (i.e., set of afferent/efferent connections) that causes pruney-ness.*

(i) *Solution:* The “rain-tread hypothesis” proposes that wet wrinkling is an efferent motor response that is due to afferent somatosensory signals related to wetness, and that the pattern of wrinkling may act to improve grip in wet conditions (see Changizi et al., 2011). A pathway connecting touch receptors in the extremities to motor efferents via the DCML, and somatosensory and motor cortices, could provide a pathway for this function.

(ii) *ChatGPT response:*

The fact that people with severed nerves connecting the hand and spinal cord don’t show the pruney response suggests that it is a result of a neural mechanism, rather than just the skin becoming waterlogged. A potential neural pathway that causes pruney-ness is as follows: Afferent nerve fibers in the skin detect changes in water exposure. These signals are transmitted to the spinal cord and processed by second-order neurons. The spinal cord sends efferent signals to the muscles in the fingers and toes, causing them to contract. This muscle contraction leads to the characteristic wrinkling of the skin seen in pruney fingers and toes. This pathway indicates that pruney-ness is an adaptive response controlled by the nervous system, likely serving to enhance grip on wet surfaces.⁷

Comments: This response, while partly regurgitating the language of the question, captures the basic logic of the desired response. It also rather seamlessly

incorporates the colloquialism “pruneyness” into its response.

Purple Peril assignments repository

To expand and improve this admittedly limited collection of questions, I have created a protected repository where instructors can access and share Purple Peril-style questions and solutions. The repository is stored as a set of files on Google Drive. Please email the author (artstats@gmail.com) for the link.

The repository includes a README file describing access, sharing and contributions. Anyone with the link can freely read, comment on, and use all exercises created by the author with attribution to the present article. Questions may be reposted on protected learning management systems (Blackboard, Canvas, etc.) but they may not be reposted to the open internet in any form. Anyone with the link can also contribute new assignments by editing one of the files named “Add More Purple Perils Here.” Once a new Purple Peril is added, permissions for that file should be reset to allow editing by Daniel Graham (artstats@gmail.com) and the contributor, as well as viewing and commenting by anyone with the link. If no editable files are available for new contributions, please email the author and more will be added.

Invitations for users and contributors will be solicited on various listservs related to perception (CVNet, Visionlist, etc.) and undergraduate pedagogy (APA Division 2, Undergraduates at Psychonomics group, CogSci-LAC), as well as through other publicity.

Discussion

I have presented an approach to creating substantive assignments in quantitative reasoning for the undergraduate sensation and perception classroom, using Gibson’s Purple Perils as inspiration. The idea in both the original Purple Perils and in the present repurposing is to cultivate critical thought. Because creativity and logic are called on in this set of assignments, they are somewhat, but not fully, resistant to illicit AI assistance. Collaborative community engagement is encouraged to expand on this work to build more and better pedagogical tools for introductory sensation and perception and related areas. The community may also find it profitable to use these kinds of

assignments as a laboratory for devising new strategies to come to terms with the increasing accessibility of advanced AI to students.

Notes

1. Note that if information is lost by the artist/observer – e.g., due to cataracts – then one can cautiously interpret resultant paintings in light of the visual deficit, as has been done in relation to Monet, e.g., Marmor & Ravin, 2009; see also Graham & Meng, 2011.
2. When asked the question posed as in the assignment, the system was slightly more skeptical but remained largely agnostic, and did not mention the logical fallacy:

The astigmatism hypothesis as the reason for El Greco's elongated figures in his paintings is not a widely accepted explanation among art historians. While it is possible that the artist may have had astigmatism, there is no concrete evidence to support this theory. Other factors, such as stylistic choices, the influence of Byzantine and Mannerist art, and a desire to convey a spiritual or emotional quality, are also considered possible reasons for the elongation seen in El Greco's figures. Until more evidence is found, the astigmatism hypothesis remains speculative.

3. One could, however, argue that the number of photons of any wavelength produced by a nightlight is too small to affect rod adaptation.
4. Also available on YouTube: "Shepard Tones," <https://www.youtube.com/watch?v=UXIR4wH971g>.
5. Prompt: "Explain the Shepard Tone Illusion."
6. Prompt: "Explain why the C, M and Y layers are necessary for printing full-color images, and why the K layer is in theory unnecessary. Why do you think the system has the unnecessary K layer?"
7. Prompt:

Everyone has experienced pruney fingers and toes. This is what happens when you spend a long time in the water. Most people, including

many perception scientists, have long assumed that the skin simply becomes waterlogged and wrinkles naturally like a wet piece of paper. But people whose nerves that connect the hand and spinal cord have been severed do not show this response. What does this tell you about the neural mechanisms of pruney-ness? Describe a potential neural pathway that causes pruney-ness.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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