Visual signals from real-life and rendered iridescent objects

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ABSTRACT:

Unlike colours arising from absorption-pigments, such as red, green, or blue paints, iridescence is remarkable for its dynamic, colour-changing nature. Since the appearance of iridescent objects is contingent on the geometry between the observer, object, and light source, we aim to characterise participants' perception of iridescence in a range of various interactive tasks and visual contexts. Here we describe two studies: (1) a free-naming task in which participants were asked to describe the material and appearance of a rotating beetle-like object, which was rendered to have different surface properties and in multiple lighting environments, and presented on a bespoke High Dynamic Range (HDR) display, which allowed reproduction of the dramatic shifts in hue and luminance often exhibited by iridescent objects as they move; and (2) a pilot study that aimed to characterise participants physical interactions (such as tilting and rotating behaviour) with real stimuli in a task that required them to capture different visual properties of iridescent and non-iridescent tiles in a single photograph. Preliminary analyses of both studies suggest that (1) verbal labels are used sufficiently consistently by naïve participants when describing complex material appearances to allow systematic comparisons to be drawn across lighting environment and physical surface properties; and (2) that participants make stereotyped manipulations of real samples when visually exploring surface properties.

1. INTRODUCTION

Iridescence describes the colour percepts that are produced through the interference of light caused by nanostructures in the surface of materials. Unlike traditional, fixed-colour properties like red, green, or blue, iridescence is remarkable for its dynamic, colour-changing nature. However, relatively little is known about the perception of iridescence, in particular how it affects our judgements of the properties of a material such as its base colour or surface coating. Recent studies with animals, such as honeybees, are beginning to explicitly test the multi-dimensional nature of iridescence by separating its spatial component, referring to the collection of hues produced by the material, from its temporal component, referring to angular variations in hue [1]. A recent study suggests that depending on the task, participants flexibly use the different views of iridescence, its temporal component, to make perceptual judgements about visual properties such as colour or material[2].

The first study we present delves into how participants employ descriptor words in the absence of any guidance from researchers and predefined dimensions. This study's objective is to see whether, without specific instructions, participants naturally use words that imply differentiation between surfaces classified by researchers as either iridescent or non-iridescent.

The second study investigates a participant's manipulations of iridescent and non-iridescent glass tiles. These manipulations are guided by specific questions that direct attention to the material's substrate colour, texture, and material properties. However, it is essential to bear in mind that, in real-world scenarios involving physical objects, observers often need to physically manipulate the objects to extract information from the iridescence. In this experiment, our primary aim is to validate whether participants exhibit a flexible use of information contingent upon the task.

2. NAMING EXPERIMENT METHODS

(Collaboration with Pascal Barla and Sylvia Pont)

Methods. In the free-naming experiment, 10 participants with normal or corrected-to-normal acuity and normal colour vision took part in the study. The stimuli were videos of the same rotating beetle-like object rendered in combinations of five surface coatings (metallic and four optical-path-length-differences (OPDs)) and two roughness levels (rough or smooth), as shown in Figure 1A. These rendered objects were presented in four lighting environments: Ennis, Glacier, Nature, Uffizi (Figure 1B). The stimuli were presented on a High Dynamic Range (HDR) display [3]. The utilisation of rendered objects not only enabled precise manipulation of iridescence levels but also allowed us to control their presentation on the HDR display. The purpose of using the HDR display was to best replicate the real-life situations in which participants see iridescent objects. Moreover, the HDR display extends the spectrum of available colours and contrasts, thus enhancing the constancy of iridescence capture.

At the beginning of the experiment participants were presented with examples of descriptor words such as: metal, plastic, glossy, matte, red, azure, smooth, bumpy, beautiful, heavy, and fragile. Participants were instructed to describe the object's material, aiming to use at least 2-3 descriptive words while being encouraged to use as many short words or phrases as possible. To capture the words and phrases that participants employed, a person was present in the room with the participant, transcribing their exact response on a laptop. Participants were not given the opportunity to go back through trials and change their answers.

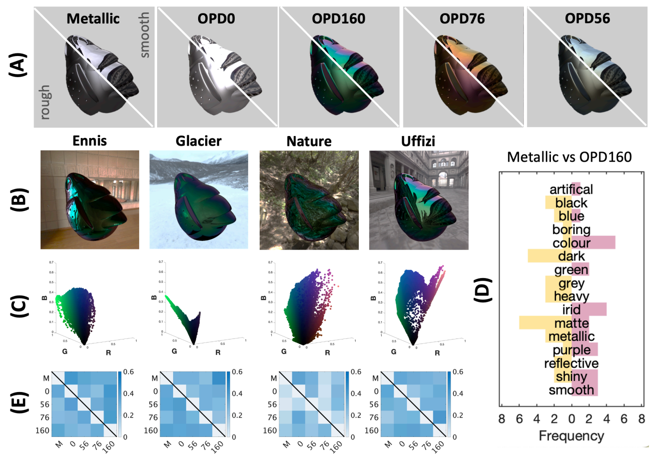

Figure 1. (A) five surface coatings, metallic and four iridescent types varied by OPD (optical path difference), to have either a smooth (top) or rough (bottom) texture, **(B)** Lighting environments. **(C)** Tone-mapped RGB intensities for OPD160 in each environment. **(D)** top 10 descriptors and their frequencies for rough metallic and rough OPD160. **(E)** Bray-Curtis dissimilarity between pairs of smooth (top) and rough (bottom) stimuli in each environment, darker colours represent higher dissimilarity.

Findings. The descriptors for each stimulus and environment combination were aggregated across all participants and their frequencies were obtained. The frequencies inform us about how much observers overlapped in their descriptions of the stimuli, and furthermore, how similar pairs of stimuli are relative to each other. An example comparison showing the 10 most frequent descriptors used to describe rough Metallic and rough OPD160 is shown in Fig. 1D. Our preliminary finding suggests that even without explicit prompting, there is a consensus among participants regarding the use of specific common descriptors. These included: reflective, iridescent or iridescence, smooth, matte. The Bray-Curtis dissimilarity index is commonly used in ecology to quantify the species-based compositional dissimilarity between two different sites. Here we calculated dissimilarities based on counts of each word used for pairs of stimuli. Key findings were that (i) lighting environments differed in the dissimilarities of materials rendered within them (e.g., under the Nature environment, stimuli appeared more similar to one another than under the Uffizi environment); and (ii) the rough stimuli were more consistently dissimilar than the smooth stimuli.

3. PHYSICAL INTERACTIONS WITH IRIDESCENCE

In the second study, we tested whether participants' flexible weighting of information extends to systematic manipulation of physical objects.

Methods. One participant with normal or corrected-to-normal acuity and normal colour vision took part in this experiment. The stimuli were 10 commercially available blue glass tiles (five non-iridescent, five iridescent), see example photographs in Figure 2. The tiles were presented in the middle of a viewing platform with a matte black surface. The participant could view a 1cm by 1cm area of the stimuli and engaged with the stimuli by physically manoeuvring the platform bearing the specific tile. To measure how participants manipulated the tile samples under different instructions, we recorded the tilt of the tile as the participant was viewing the tile using an iPhone placed inside the viewing platform. The participants were not aware that the platform recorded movement. This experimental setup allowed us to investigate how the participant actively sought specific viewing angles based on the instructions to best capture (1) the substrates colour, (2) the surface texture, and (3) how it was made.

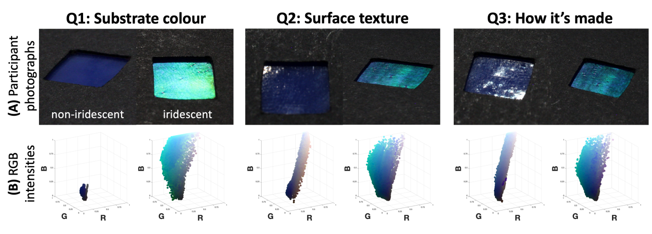

Figure 2. (A) Participants' photographs of the same non-iridescent (left) and iridescent (right) tiles taken for each instruction. **(B)** Raw camera RGB intensities of pixels containing the stimulus.

Findings. Participants systematically selected different viewing conditions to convey different material properties, as indicated by the captured photographs in Figure 2. The manipulations they made also hinted at stereotyped manipulations to elicit specific percepts (e.g. small oscillatory motions to alternate between angles where iridescence is visible and not), but more data is required to test the reliability and generalisability of these findings. This has relevance for how material properties may be conveyed in e-commerce applications.

4. CONCLUSION

Results from the free-naming study with naïve participants show that participants have similar interactions with iridescent materials across diverse contexts, and that the availability of signatures of iridescence is dependent on the lighting environment. With the active manipulation and photography task, the participant exhibited stereotyped behaviours to characterise and engage with the set of iridescent objects presented.

5. WHAT I'VE LEARNED

Over the 12 weeks I have been in Professor Hannah Smithson's Oxford Perception Lab at the University of Oxford, I can confidently affirm that my skills and knowledge have improved significantly compared to the beginning of summer. During my time in the lab, my focus has centrally been on iridescence and subtopics within perception. In doing so, I have learned about designing 3D shapes in Blender, working with human participants and taking informed consent. In addition, I was introduced to MATLAB and learned basic functions and concepts within computer programming, which has allowed me to begin constructing my own code to organise and visualise data. Enabling me to expand my horizons within experimental psychology this experience has been truly enlightening. Working with a dynamic and enthusiastic research team, my passion for research has been confirmed, and it has motivated me to learn the skills needed for independent research. Looking toward the future, I am positive that my experience in the Oxford Perception Lab and the knowledge gained during the summer will serve as a strong foundation for my future research endeavours.

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7. REFERENCES

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