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Contextual effects on real bicolored glossy surfaces

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The material property of glossiness, which is attributed to many objects in our daily life, is physically independent of the objects' color. However, perceived glossiness can change with the contrast between the highlight and the area around the specular highlight. Hitherto, experiments mainly investigated gloss on unicolored surfaces. It is well known that the context in which a surface is embedded can influence its perceived lightness. Here we investigated whether similar contextual effects exist also for gloss perception by presenting single surfaces containing two different colors. We tested the influence of the second color on participants' gloss judgments with both real surfaces and photographs of those surfaces. In both conditions, participants were influenced by the second color on the surface even though they were asked to ignore it. We found contrasting contextual effects on the bicolored surfaces. However, when explicitly asked to rate the global gloss on the bicolored surfaces, participants took both parts of the surface equally into account.

Introduction

The amount of specularly reflected light reaching our eye from a glossy surface depends on the light field, the shape of the object, and the viewing position. A large number of experiments have already investigated the effects of the illumination field (Doerschner, Boyaci, & Maloney, 2010; Fleming, Dror, & Adelson, 2003; Motoyoshi, & Matoba, 2011; Ollkonen & Brainard, 2010, 2011; Pont & Te Pas, 2006), shape (Fleming, Torralba, & Adelson, 2004; Ho, Landy, & Maloney, 2008; Marlow & Anderson, 2013; Nishida & Shinya, 1998; Vangorp, Laurijssen, & Dutré, 2007; Wijntjes & Pont, 2010), highlight position and orientation (Beck & Prazdny, 1981; Kim, Marlow, & Anderson, 2011; Marlow, Kim, & Anderson, 2011), and motion (Doerschner et al., 2011; Hartung & Kersten, 2002; Wendt, Faul, Ekroll, & Mausfeld, 2010) on perceived gloss. However, most objects in our daily environment are made out of more than one material and are embedded in a larger context. This makes it interesting to ask how the presence of multiple surface materials might affect the perceived gloss of surfaces. Contextual effects in lightness perception are commonplace, with simultaneous contrast being probably the most famous example (among many others). Two patches of the same shade of gray are displayed against different backgrounds and differ in their perceived lightness (first described by Chevreul, 1839; see Adelson, 2000, and Kingdom, 2011, for an overview).

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Contextual effects in gloss perception, however, have not yet been extensively described. Fleming et al. (2003) rendered glossy spheres, cut them out of their original background, and placed them in front of a new background. This procedure had only little effect on perceived gloss. Doerschner et al. (2010) instead placed real painted spheres in front of white and black backgrounds, and they found that spheres were perceived glossier in front of the black background than when presented in front of the white background. Both studies used objects consisting of only a single material. It remains unclear how multiple materials on single objects influence each other.

Here we investigate perceived gloss on surfaces containing more than one material to investigate the contextual effects that a second material might have. Instead of rendering objects we use real surfaces, which we spray-painted in two different colors, and various gloss levels. In addition, in a second experiment, we use photographs of those real surfaces. Previous studies already investigated the influence of the color/albedo on perceived gloss. Hunter (1937) indicated that contrast gloss constitutes one of the six subjective dimensions of gloss, and he showed that subjects pay attention to the contrast between the highlight and the nonhighlight area on a surface. More recently, Pellacini, Ferwerda, and Greenberg (2000) and Ferwerda, Pellacini, and Greenberg (2001) found that darker surfaces are perceived to be glossier than lighter surfaces, an effect that is to be expected if observers use the highlight contrast as a cue. Marlow, Kim, and Anderson (2012), on the basis of their psychophysical results, also argued that contrast gloss is one of the important features when judging gloss. Based on those studies, it can be assumed that surfaces that are constructed out of more than one color can also exhibit two different percepts of gloss for each color separately. If this is the case, it remains unclear whether those two percepts can influence each other or whether they are independent. In addition, it also remains to be established how we perceive the overall gloss of a surface that is made out of two different colors with the same physical gloss.

Material and methods: Experiment 1

In Experiment 1 we investigated the contextual effects using real surfaces.

Stimuli

The mesh for our stimuli was created using Mathematica 9.0.1. We chose a set of "sharp" contours, which we subsequently smoothed by convolving with a Gaussian. The exported object file was used by the Computer Numerical Control machine to cut out molds. Polymer foam was used as the material for the molds (Figure 1a). Our molds had dimensions of 250 × 250 mm. Each stimulus was produced out of a larger 350- × 350- × 1-mm polystyrene thermoplastic sheet to account for additional material on the sides since the plastic sheets had to be clamped into a metal frame on all sides when positioned into the forming machine. Stimuli were produced using a thermoforming machine. The mold was placed into the machine with the flat thermoplastic sheet in top, which was heated until it became moldable. The plastic sheet was then pressed onto the mold, taking up its profile by withdrawing the air between mold and plastic via small air holes in the mold (Figure 1b). A black velvety frame later covered this additional plastic frame.

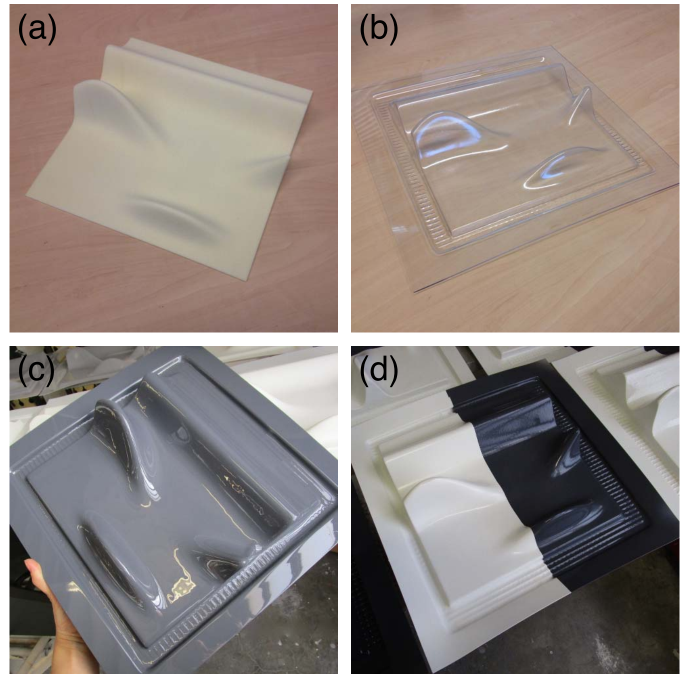

Figure 1. Real object construction. (a) Photo of the mold made out of polymer foam. (b) The prototype of one stimulus after the vacuum-forming process. (c) Unicolored spray-painted surface. (d) Bicolored surface after spray-painting both parts.

We chose a wide range of colors and gloss levels with the constraint that the differences between the gloss levels and colors were approximately perceptually equal. The selected colors were based on the European color matching system (RAL). We compared RAL color samples to a Kodak gray scale (with 20 perceptually equal gray levels steps) and selected RAL colors that corresponded to equally spaced steps on the Kodak scale. We selected five colors in total, ranging from white to black (RAL 9010: Pure white; RAL 7036: Platinum gray; RAL 7015: Slate Gray; RAL 7021: Black gray; RAL 9005: Black). To assure equally

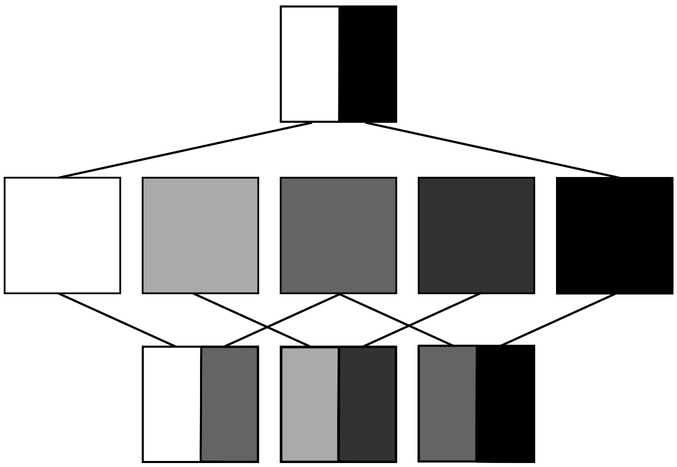

Figure 2. Overview of all four color combinations for the bicolored surfaces.

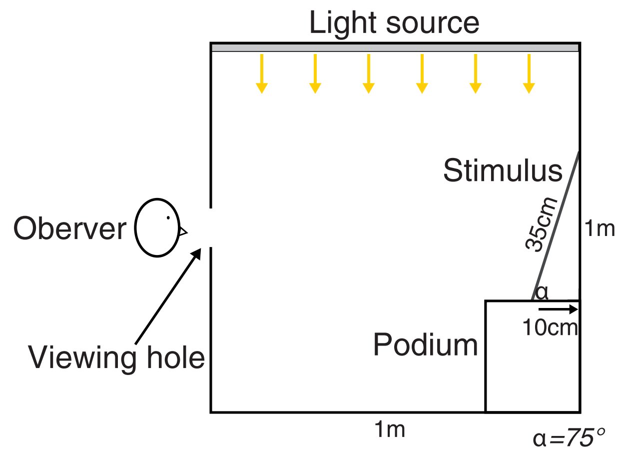

Figure 3. Side view of the setup. Each stimulus was placed onto the podium in the light booth. Two markers on the podium indicated the exact position of the surface. The bottom base of the surface was always placed 10 cm away from the wall. The upper edge of the surface was leaning against the wall.

spaced steps for different gloss levels we based our selected gloss units on a Maximum Likelihood Difference Scaling (MLDS) experiment by Obein, Knoblauch, and Vienot (2004). We chose gloss units (GUs) that corresponded best to their MLDS data ranging from matte to high gloss. We selected five gloss levels in total (gloss units: 5, 17.5, 50, 70, or 90 GU) and spray-painted each surface with one layer of acrylic paint and let it dry for 24 hr. For some samples we also combined two colors on one surface, by covering half of the surface with paper and then spray-painting the other half with a second color (see Figure 1d for an example).

In total we spray-painted 25 unicolored surfaces (5 Gloss levels × 5 Colors). The bicolored surfaces were always a combination of two colors with the same gloss level. To enhance the contrast between the two colors on the surface, we always chose two colors from our linear color space, which had at least one sample in between (the lower row in Figure 2). In addition we also spray-painted a stimulus combining the lightest and darkest color to create a maximum contrast (upper combination in Figure 2). Thus, we spray-painted four color combinations for each of the five gloss levels, yielding a total of 20 biolored surfaces.

In order to hide the clamp edges from the forming process and to create a neutral surrounding we made 5-mm-thick cardboard frames and covered them with black velvety light absorbing black-out material (Edmund Optics, Barrington, NJ).

Apparatus

Stimuli were presented in a light booth consisting of a large 1- × 1- × 1-m metal box. The complete ceiling of the box consisted of a white opal glass plane of 1 × 1 m that was backlit by fluorescent tubes resulting in a homogeneous illumination from above (see Pont & Koenderink, 2003, for a detailed description). All walls and the floor of the metal box were covered with a black velvety curtain. Each stimulus was placed upright onto a small podium so that the height of the center of the stimulus corresponded to the center of the viewing hole (Figure 3). Lights in the experimental room were kept on, since the luminance in the box was quite high.

Procedure

On each trial participants saw a single surface inside the light booth with both eyes. The task was to rate the gloss on a scale from 1 to 7. Prior to the experiment participants were shown a white matte and a highly glossy black surface as examples of both extremes of the rating scale. Participants were provided with a paper response sheet to indicate their ratings for each trial. The experiment consisted of two parts: In the first part participants were presented with 45 stimuli in total (25 unicolored and 20 bicolored) and the task was to rate the overall gloss of the surfaces. During the second part of the experiments participants were presented twice with each of the bicolored surfaces (20 surfaces) in a random order, and the task was to rate either the left or the right half of the surface, resulting in 40 judgments in total. Which half was to be judged was indicated on the paper response sheet (left or right) and also mentioned by the experimenter at the beginning of each trial. Altogether, this resulted in a total number of 85 judgments per participant.

In between each trial the experimenter removed the surface from the light booth and placed the next surface into the light booth. The experimenter announced the next trial and then the participant could look into the light booth to prevent the participant from using object motion cues during the replacement of the stimulus. It is probable that participants moved their heads while looking at the surfaces, which offered them additional information to separate the diffuse and specular layer. All participants were standing in front of the booth, while looking inside through the 8-cm-diameter viewing hole. Participants could use as much time as needed to make their judgment. Between the two parts, participants could take a break and the complete experiment lasted for about 2.5 hr in total.

Observers

Eleven observers (four male and seven female, age between 24 and 35 years) participated in the experiment. All participants were naive to the purpose of the study and had normal or corrected-to-normal vision. They all gave written, informed consent. All experiments were done in agreement with the local ethics committee from TU Delft and the Declaration of Helsinki.

Material and methods: Experiment 2

In the second experiment we replicated the first experiment using photographs of the real surfaces.

Stimuli

Photographs of the surfaces from Experiment 1 were used. All photographs were taken with a linearized Canon EOS 5D Mark II Camera and a Canon EF 24-70mm f/2.8L lens (Canon, Inc., Tokyo, Japan). Luminance values of a 12-steps gray card when placed inside the light booth were compared with the luminance values of that gray card when presented as a photograph on a computer monitor to ensure the linearity of our photographs. Moreover, we plotted the luminance histograms (Figure 4) of the glossy white and light gray surfaces to verify that the highlights were not clipped. The brightest pixels in the center of the highlight on a white surface correspond to 98% of the maximum luminance on the screen.

Apparatus

All photographs were displayed on a 24-in. calibrated LCD flat screen (ViewSonic V3D245) with a linear gamma. The resolution of the screen was 1920 × 1080 pixels. All stimuli were displayed using Matlab R 2010a and Psychtoolbox-3 (Brainard, 1997) running on a MAC Pro Quadro-Core Intel Xeon with OSX 10.5.8. All photographs included the object with its black velvety frame and each photograph was displayed against a dark gray (0.3 0.3 0.3) background. The size of each photograph on the screen was chosen so that it matched the visual angle of the objects in the light booth. Each single image subtended 19.8 × 19.8 (715 × 715 pixels) degrees of visual angle on the LCD screen (ViewSonic V3D245, ViewSonic Corporation, Brea, CA).

Procedure

The general procedure for this experiment was kept identical to the procedure of Experiment 1. Participants were seated with their chin placed into a chinrest and viewed the photographs binocularly. The images did not contain binocular disparities, so from a stereoscopic perspective, the stimuli were consistent with flat objects. After each trial, participants indicated their ratings by clicking with the mouse on the appropriate number on the screen.

Observers

Fifteen observers (seven male and eight female, age between 21 and 32 years) participated in the experiment. All participants were naive to the purpose of the study and had normal or corrected-to-normal vision. They all gave written, informed consent. All experiments were done in agreement with the local ethics committee from Université Paris Descartes and the Declaration of Helsinki. For data analysis we had to exclude two participants who did not understand the task. These two participants appeared to judge the lightness of the object instead of its glossiness. Their data did not exhibit any difference in perceived gloss between a matte and a glossy object of the same color.

Results: Experiment 1

Influence of the color on perceived gloss

For the forthcoming analysis we refer to the two tasks as follows: gloss ratings in isolation on a unicolored surface and gloss ratings in context on a bicolored surface. For the latter task, the color that has to be rated is called “target color” and the other color on the surface is called “context color.”

To be able to compare results against a baseline for unicolored surfaces and better to evaluate the influence

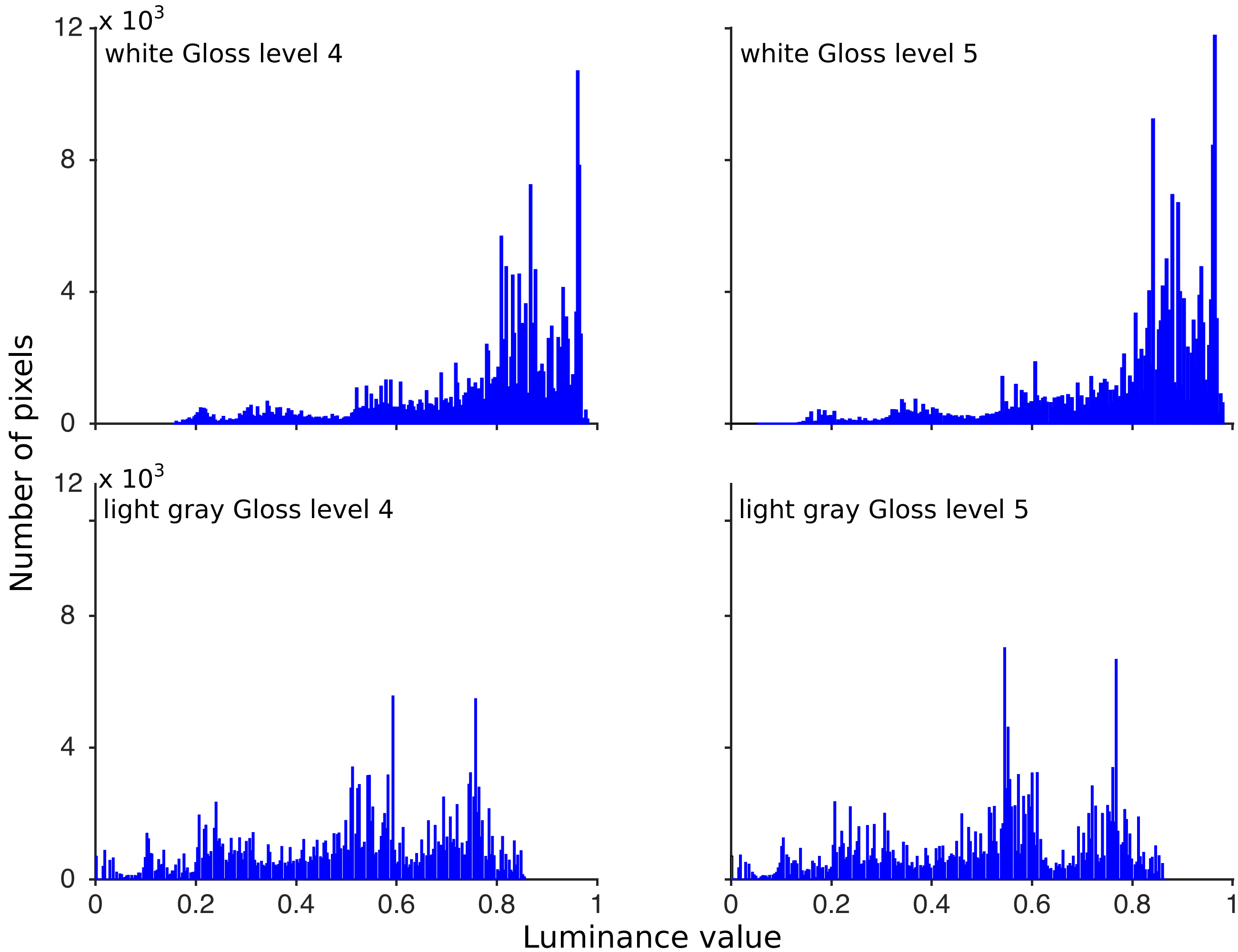

Figure 4. Luminance histograms of the glossy white and light gray surfaces. The luminance histograms displayed here correspond to the photos that were shown in Experiment 2.

of different colors on a single surface, we first investigated the effect of a single color on perceived gloss. Figure 5 plots the gloss ratings as a function of the different gloss levels for all five colors. Gloss ratings from 1 to 7 were rescaled from 0 to 1 here and in all subsequent analyses. A repeated-measures analysis of variance (ANOVA) with two within-subjects factors (color and gloss level) verified that the gloss ratings were significantly affected by the surface color, $F(4, 40) = 15.17$, $p < 0.001$, and the gloss ratings are affected by the physical gloss of the paint, $F(4, 40) = 290.5$, $p < 0.001$. Furthermore we found a significant interaction between color and gloss level, $F(16, 160) = 7.598$, $p < 0.001$.

Contextual effects

We also analyzed how perceived gloss varies with the two different types of presentation: presented in isolation or when the same color was presented in context.

The results of the contextual effects are presented in Figure 6. In each diagram we compare the gloss ratings on a unicolored surface with the gloss ratings of the same color in context with a second color. The left diagram plots all data from judging the gloss of a lighter color next to a darker color against perceived gloss of that color in isolation. The right diagram plots all gloss judgments of a darker color next to lighter colors against perceived gloss of that color in isolation. We used linear regression to investigate the influence of the context. Data points below the identity line are indicating a decrease of perceived gloss in context, and data points above the identity line indicate an increase in perceived gloss when its rated in context. The slope was statistically tested against 1 with a one-sample t test. The slope ($b = 0.72$, $CI = 0.113$) in the left diagram was significantly smaller than 1, indicating that perceived gloss on a lighter colored half was reduced when presented next to a darker half on the same

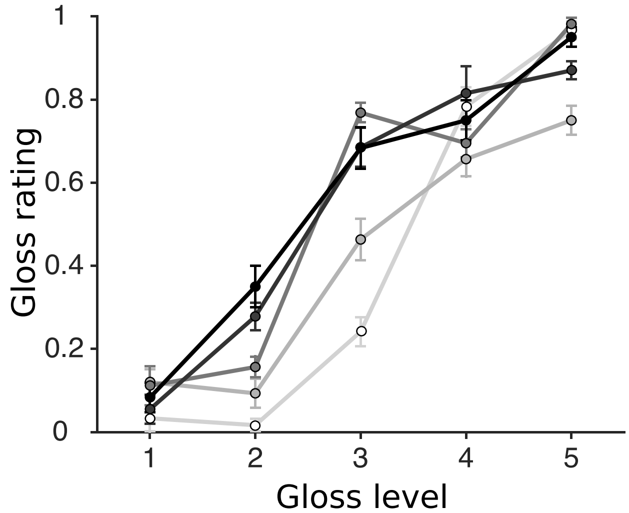

Figure 5. Perceived gloss of unicolored surfaces. The *x*-axis represents the five gloss levels and the *y*-axis represents the gloss ratings. The color of the lines corresponds to the color on the surface. Error bars are the standard error of the mean across participants.

surface, $t(18) = -4.87$, $p < 0.001$. This reduction in perceived gloss is found to mainly affect the glossiest surfaces. The lighter colored half on the surface did not affect gloss ratings of the darker half on the bicolored surface (Figure 6b). The linear regression line (slope: $b = 1.04$, $CI = 0.14$) did not change significantly from the identity line, $t(18) = 0.62$, $p = 0.55$.

Gloss averaging

We also analyzed participants' overall ratings of bicolored surfaces to understand how participants evaluated the global gloss on a bicolored surface and whether they are able to take both sides evenly into account. The results are presented in Figure 7.

Not too surprisingly, the global gloss ratings were in between the ratings of the unicolored surfaces (shown in Figure 5). The slope ($b = 1.01$) was statistically tested against 1 with a one-sample t test but did not deviate from 1, $t(18) = 0.11$, $p = 0.91$. The perceived gloss on the bicolored surfaces correlated well with the predicted gloss ratings.

Results: Experiment 2

In Experiment 2 we presented the surfaces as photographs on a LCD screen. Figure 8a shows the data obtained for rating the unicolored surfaces. We

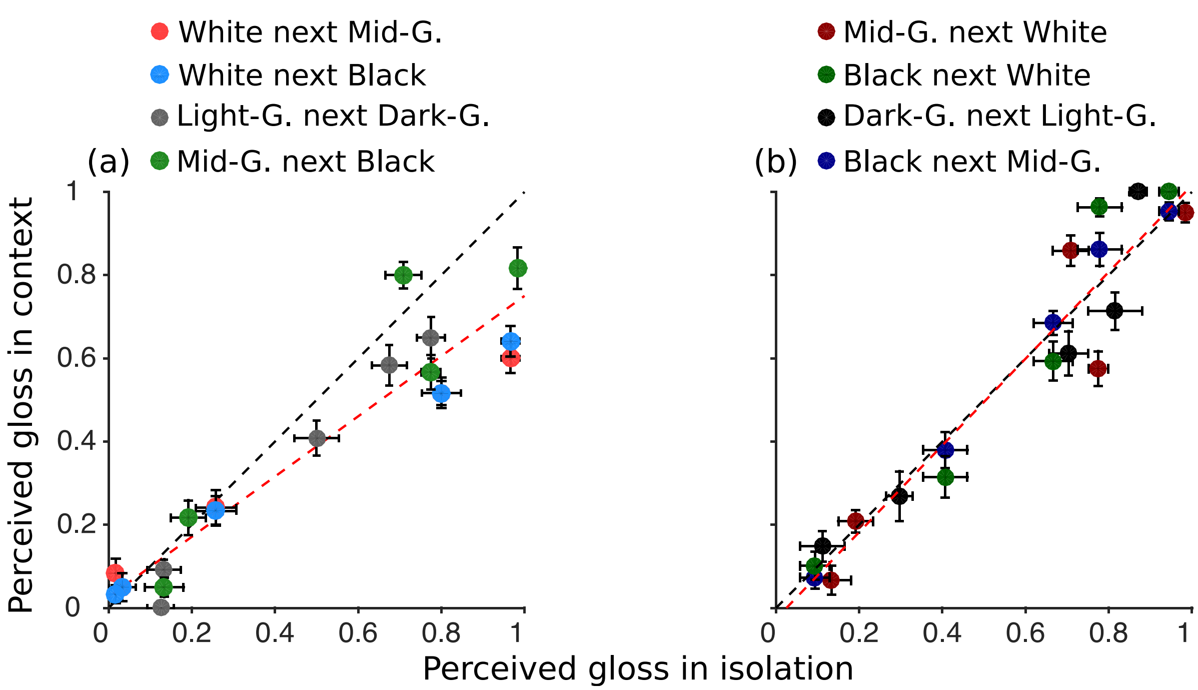

Figure 6. Contextual effects for real surfaces. Both diagrams plot the perceived gloss in context on a bicolored surface as a function of perceived gloss in isolation on a unicolored surface. Each color denotes a specific color combination on the surface. Diagram (a) plots all color combinations where the gloss of a lighter colored half of a surface was rated in context of a darker color, and Diagram (b) plots all color combinations in which the gloss of a darker colored half of a surface was rated in context of a lighter colored half. The black dashed line indicates a constant participant that has no influence of the context. The red dashed line denotes the linear regression line fitted through all data points. Error bars are the standard error of the mean.

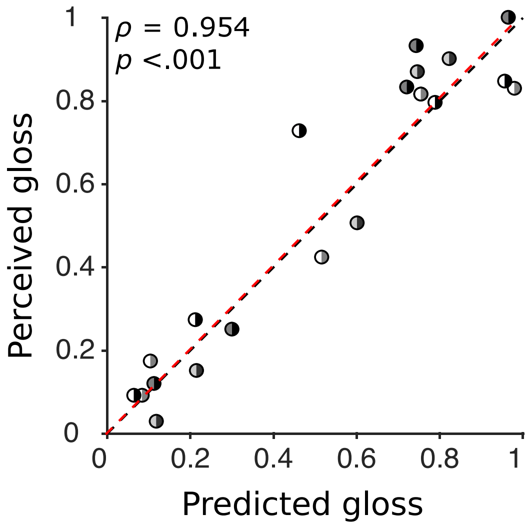

Figure 7. Data from the gloss averaging task when the surfaces consisted of two different materials. Perceived gloss of a bicolored surface is plotted as a function of predicted gloss. The predicted gloss was calculated by taking the average rating of the two corresponding colors in isolation.

found a strong influence of the surface color on perceived gloss, replicating the results from Experiment 1. Perceived gloss on surfaces with lighter colors was lower than the gloss ratings on surfaces with darker colors.

We also noted a large variability in the ratings of the highly glossy (Gloss level 5) white surface when using photographs. We therefore plotted a histogram of all ratings for this white surface separately in Figure 8b and we found a distribution with two modes. Participants either perceived this white surface as almost matte (red bars) or as glossy, similar to what we found for the real surfaces (blue bars). This motivated us to split our participants into two groups representative of these two modes. We decided to split the data between gloss levels 3 and 4. Since we had an uneven number of participants we also ran the analysis with a split between 4 and 5. However, the results were the same. Figures 8c and d plot all gloss ratings again, but split into the two groups. Group 1 displays a similar pattern as the participants from Experiment 1. A repeated-measures ANOVA with two within-subjects factors (color and gloss level) verified that the gloss ratings were significantly affected by the surface color, $F(4, 24) = 17.61$, $p < 0.001$, and the gloss ratings are affected by the physical gloss of the paint, $F(4, 24) = 135.2$, $p < 0.001$. Furthermore we found a significant interaction between color and gloss level, $F(16, 96) = 4.664$, $p < 0.001$.

Group 2 displays a different pattern for the glossy white surfaces and also partly for the light gray surfaces. For this latter group, a physically highly glossy white surface was judged to be almost matte. For the darker colors we do not observe a difference between the two groups. A repeated-measures ANOVA with two within-subjects factors (color and gloss level) verified that the gloss ratings were significantly affected by the surface color, $F(4, 20) = 42.28$, $p < 0.001$, and the gloss ratings are affected by the physical gloss of the paint, $F(4, 20) = 41.66$, $p < 0.001$. Furthermore we found a significant interaction between color and gloss level, $F(16, 80) = 4.42$, $p < 0.001$. Gloss ratings of the white surface were also affected by the physical gloss of the paint, $F(4, 20) = 15.27$, $p < 0.001$. However, follow-up paired t test at the Bonferroni-corrected level revealed that only the results for gloss levels 4 and 5 differ from those for the other three gloss levels.

Contextual effects

The results for Group 1 are presented in Figure 9. Similar to Experiment 1, we found that gloss ratings are indeed influenced by the second color: Perceived gloss of lighter colors which are rated next to darker colors decreased (left diagram), whereas rating the gloss of a darker color next to a lighter color did not indicate any contextual effects (right diagram). Those results were statistically confirmed by testing the slope ($b = 0.65$, $CI = 0.19$) of the linear regression, fitted to the data points, against 1. Similar to the results in Experiment 1, the slope in the left diagram deviates significantly away from 1, $t(18) = -3.70$, $p = 0.002$, indicating a reduction in perceived gloss when the lighter colored half is presented next to a darker half, whereas perceived gloss of the darker half (right diagram) was not affected by the lighter colored half (slope: $b = 0.976$, $CI = 0.12$, one-sample t test: $t[18] = -0.34$, $p = 0.74$).

Figure 10 plots the gloss ratings for all participants from Group 2. Participants in Group 2 perceived a glossy white surface as almost matte and therefore gave really low gloss ratings. Those ratings are stable independent of whether white is presented in isolation or in context with a second color. However, we still find a small but significant decrease in the slope ($b = 0.88$, $CI = 0.104$) fitted to our datapoints, $t(18) = -2.32$, $p = 0.03$, confirming the decrease in perceived gloss on a bicolored surface (Figure 10a). Rating a darker colored half on the surface next to a lighter colored half (Figure 10b) also indicated a small effect of the context where perceived gloss is decreased in context (slope: $b = 0.88$, $CI = 0.1$, $t[18] = -2.2$, $p = 0.04$. The majority of data points are falling below the identity line; however, the intercept did not deviate significantly from zero (intercept: $a = -0.067$, $SE = 0.037$, $t[18] = -1.8$, $p =$

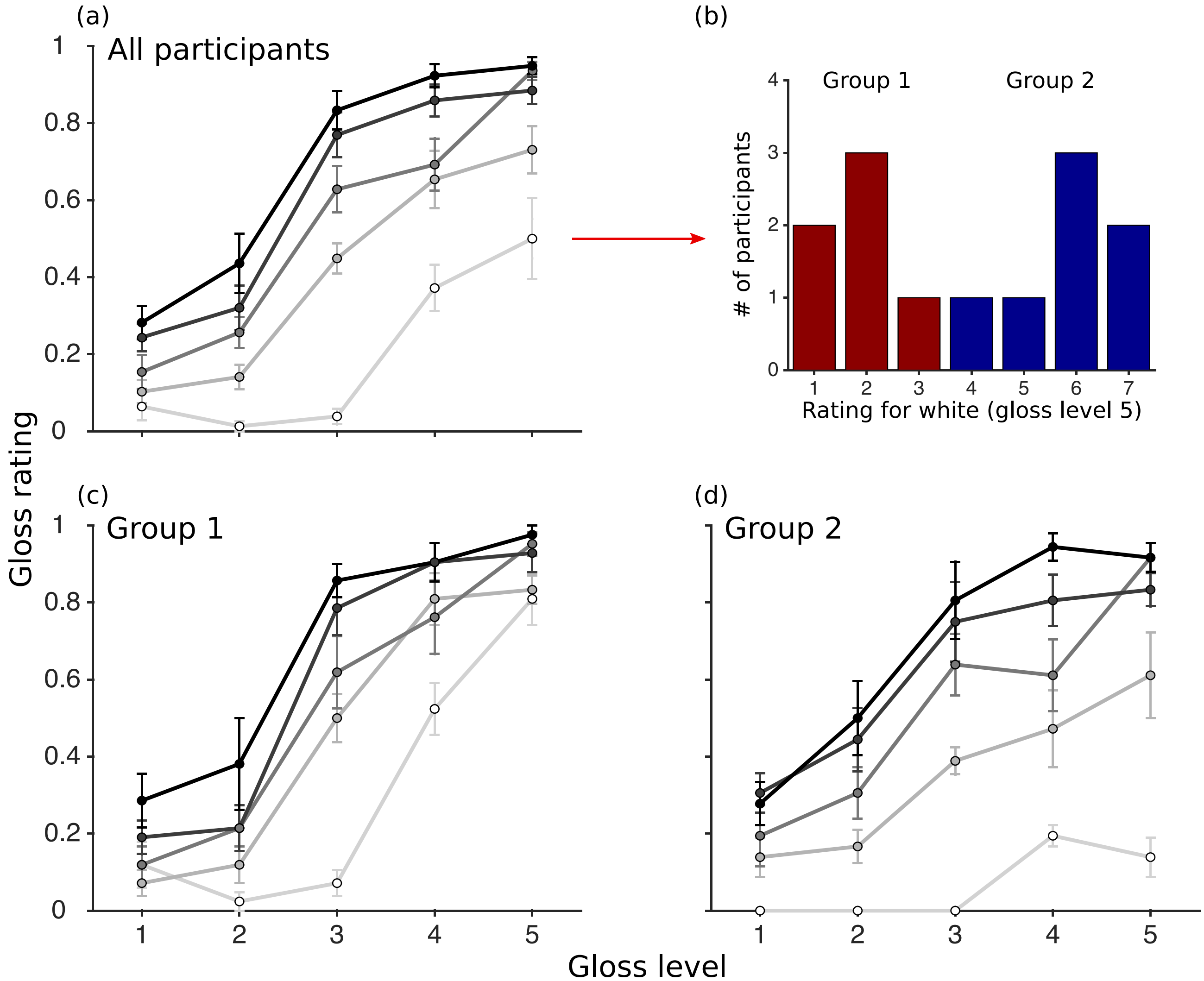

Figure 8. Perceived gloss of unicolored surfaces. Participants' gloss ratings as a function of the five gloss levels separated by the five colors. (a) Perceived gloss averaged over 13 participants for all five unicolored surfaces. (b) Individual ratings of the white surface with gloss level 5. (c) and (d) Same plotting conventions as in (a) but split into the two groups according to the distribution in (b).

0.089). Overall the data from Group 2 show a similar, but weaker, influence of the context.

Gloss averaging

We also investigated participants' ability to estimate the overall gloss on the bicolored surfaces. Figure 11 plots the global gloss ratings of the bicolored surfaces. As in Experiment 1, gloss ratings were between the gloss ratings of the two corresponding unicolored surfaces (Figure 8c, d). The slopes (left diagram: $b = 0.93$, right diagram: $b = 0.99$) were statistically tested against 1 with a one-sample t test. However, they did not deviate from 1 (Group 1: $t[18] = 0.93$, $p = 0.37$; Group 2: $t[18] = -0.13$, $p = 0.9$). Thus, perceived gloss for both group correlates well with the predicted gloss.

Discussion

The main interest of the present study was to investigate possible contextual effects on glossy bicolored surfaces. First, we confirmed that increasing the physical gloss of the paint evidently increased perceived gloss of the surface and that darker surfaces are perceived to be glossier than lighter surfaces (Pellacini et al., 2000; Ferwerda et al., 2001; Marlow et al., 2012). Moreover, our results from both experiments clearly show that a second, different material on the surface can influence the perceived gloss of the first material. We found that perceived gloss of the lighter parts on the surfaces was significantly reduced when these parts were combined with darker colors. Perceived gloss of the darker parts on the surface was less influenced by the lighter color. Contextual effects were found to be

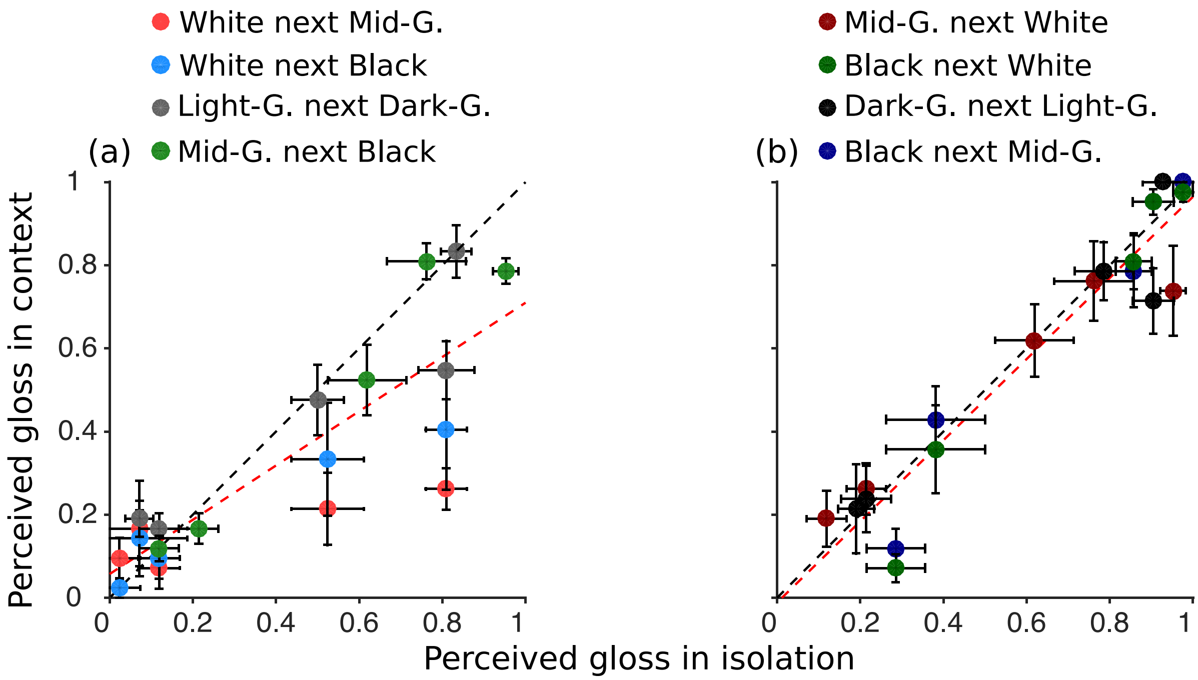

Figure 9. Contextual effects for Group 1. Both diagrams plot the perceived gloss in context as a function of perceived gloss in isolation. Each color denotes a specific color combination on the surface. Diagram (a) plots all color combinations where the gloss of a lighter colored half of a surface was rated in context of a darker color, and Diagram (b) plots all color combinations in which the gloss of a darker colored half of a surface was rated in context of a lighter colored half. The black dashed line indicates a constant observer that has no influence of the context. The red dashed line denotes the linear regression line fitted through all datapoints. Error bars are the standard error of the mean across participants.

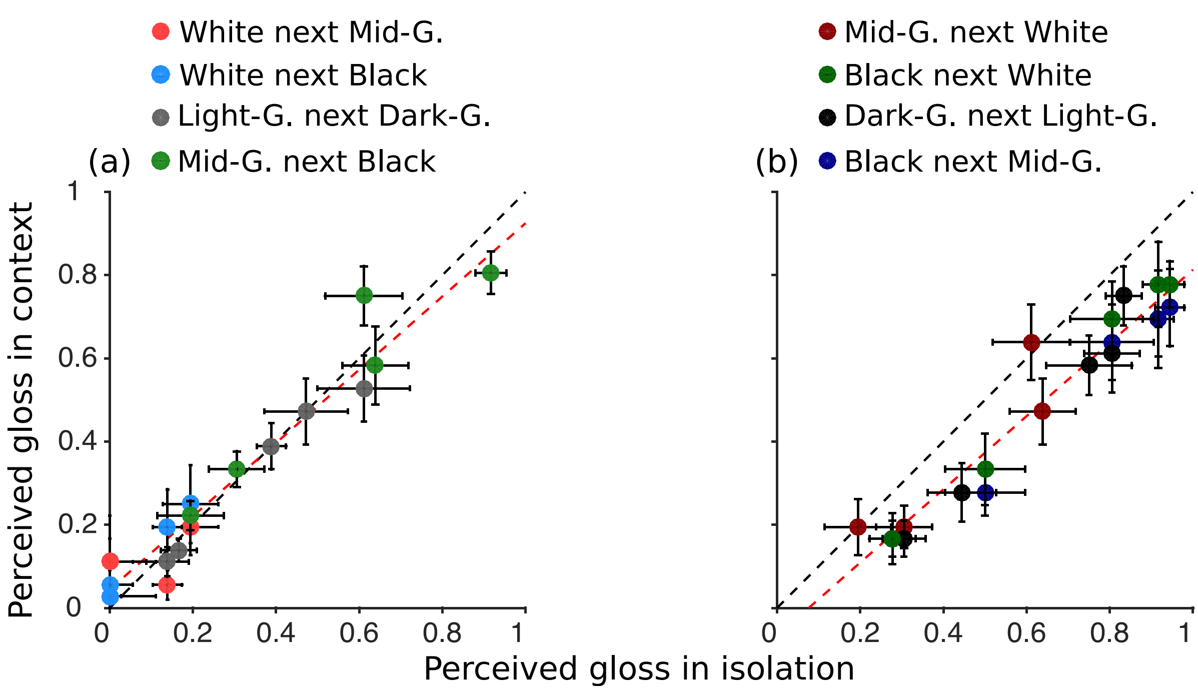

Figure 10. Contextual effects for Group 2. Both diagrams plot the perceived gloss in context as a function of perceived gloss in isolation. Each color denotes a specific color combination on the surface. Diagram (a) plots all color combinations where the gloss of a lighter colored half was rated in context of a darker color, and Diagram (b) plots all color combinations in which the gloss of a darker colored half of a surface was rated in context of a lighter colored half. The black dashed line indicates a constant observer that exhibits no influence of the context. The red dashed line denotes the linear regression line fitted through all datapoints. Error bars are the standard error of the mean across participants.

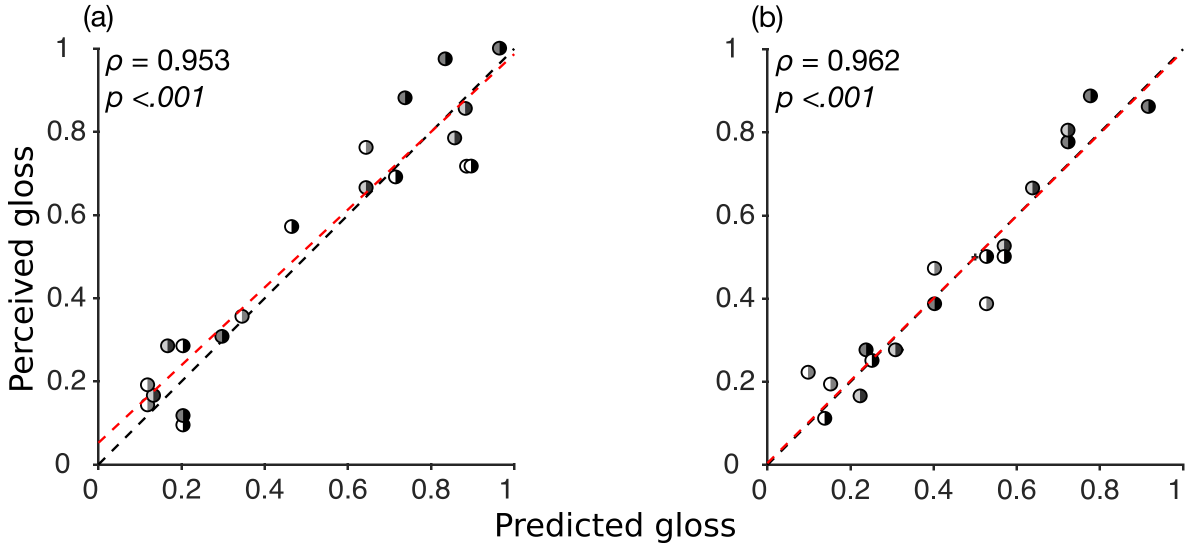

Figure 11. Global gloss ratings obtained from both groups using photographs. (a) Group 1 and (b) Group 2. Perceived gloss of the bicolored surfaces is plotted against the predicted gloss ratings. The predicted gloss was calculated by taking the average rating of the two corresponding colors in isolation.

asymmetrical for our surfaces and color combinations. These results were replicated in the second experiment using photographs. However, in this experiment we found larger interindividual differences between participants than in the first experiment. The data from Experiment 1 revealed that the contextual effects mainly occurred for mid and high gloss surfaces. In Experiment 2 a subset of our participants (Group 2) reported that the surfaces appeared matte, probably because they were not able to identify the highlights on the lighter surfaces. Such an effect of course would have limited the range of the contextual effects: Low gloss ratings could not get further reduced since they were already at the lower end of the rating scale. Therefore, strong contextual effects are only found in participants that perceived the light glossy surfaces to be glossy. In a second task we asked participants to indicate the overall gloss on the bicolored surface. The data from this gloss averaging task shows that participants are able to take both sides evenly into account.

The importance of contrast gloss that is accentuated on dark surfaces had already been described by Hunter (1937) and later systematically investigated by Pellacini et al. (2000) and Marlow et al. (2012). We confirmed their findings that contrast gloss is indeed a strong cue used by the participants when estimating gloss on a surface. To distinguish between the different gloss levels, participants might have used other cues like the coverage, the sharpness of highlights (Marlow et al., 2012), or the distinctness of image (DOI) gloss (Hunter, 1937; Pellacini et al., 2000). By carefully observing the images in Figure 12 we readily see that the coverage slightly increases across gloss levels. A more salient effect is that the highlights get much sharper with increasing gloss level, and at higher gloss levels the reflected images are more distinct. DOI gloss has been proposed in a large number of studies to play a profound role when estimating the gloss of a surface (e.g., Hunter, 1937; Obein et al., 2004; Pellacini et al., 2000; van Assen, Wijntjes, & Pont, 2016). Sharpness refers to the slope of the luminance gradient at the edges of the highlights (see also Marlow & Anderson, 2013). However, there is no common technique to estimate DOI gloss or sharpness directly from the image.

Figure 12. Photographs of the midgray surface with increasing gloss level from low gloss/matte (left) to high gloss (right).

The found reduction of perceived gloss must originate from the second material that is on the same surface. One possible explanation for this phenomenon is that participants are not only rating the gloss directly and then indicating their result but also putting their judgment into a broader context. They might perform a relative judgment by comparing the gloss of both halves. Even if the participant is asked to judge only a part on a surface, he or she might use the context as an additional source of information. This comparison might then itself influence the final percept.

The data from the experiment using real surfaces were more consistent between participants than the data from the photograph experiment, which indicated large interindividual differences. Comparing the two experiments corresponds to comparing a full cue condition with a less natural condition. One main difference between the two experiments is the conflicting binocular information and the lack of motion information in the second experiment. In the second experiment the surfaces were consistent with flat objects, which induces an overall reduction in perceived gloss (Kerrigan & Adams, 2013). Specular highlights under stereoscopic viewing appear either in front or behind the surface, depending on its curvature, and are not tied to the surface. Disparity therefore offers a strong cue to distinguish between a highlight and for instance the surface texture and pigmentation (Blake & Buelthoff, 1990; Hurlbert, Cumming, & Parker, 1991; Wendt et al., 2010; Wendt, Faul, & Mausfeld, 2008). Our results for Group 2 indicated that the white highlights on the photographs could also have been interpreted as variations of shading, illumination intensity, or albedo. These confounding effects between illumination and material have often been observed (Fleming et al., 2003; Marlow et al., 2012, 2013; Pont et al., 2006) and different interpretations might lead to large inter-individual differences in perceived gloss. Such interindividual differences were recently also found in a study in which color constancy was studied under variations of gloss and illumination (Lee & Smithson, 2016). Limiting the available cues lead to a greater number of possible interpretations, introducing a greater variability in the data.

Moreover, we cannot exclude the possibility that participants in the real experiment used some (head) motion information to separate the specular reflections from the surface color.

Other studies confirmed that this might serve as a strong cue to estimate the gloss on a surface (Hartung & Kersten, 2002; Sakano & Ando, 2010; Wendt et al., 2008). The optic flow patterns seem to have characteristic features that inform about the surface material (Doerschner et al., 2011).

While it was necessary to split our participants into the two groups to fully account for the diversity of the contextual effects, we should emphasize that all participants were similar in exhibiting a contrasting contextual effect of gloss.

Our study provides a first attempt to study contextual effects on objects with multiple materials. Similar to what has been studied extensively in lightness perception, glossy materials also interact spatially with each other, and this can lead to variations in gloss perception depending on the context.

Keywords: gloss perception, material perception, bicolored surfaces, real objects, specular highlights

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