# Time Travel with One Click: Effects of Digital Filters on Perceptions of Photographs

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## ABSTRACT

Today's digital photographs are being heavily "filtered." By simple clicks on mobile apps like Hipstamatic and Instagram, users can easily apply digital filters to their pictures to create effects such as faux-vintage and light leaks. To understand the potential impacts of photo filters, we conducted an online experiment and investigated how the use of the black-and-white and film-style photo filters changed viewers' perceptions and descriptions of photographs. We found that photo filters substantially increased viewers' perceived temporal distances to photographs. Participants also tended to describe analogue-style photos more interpretively and tentatively than unfiltered ones, indicating an increase in construal levels. We suggest that the widely used photo filter is not just a tool to change aesthetics; it also adds a layer of history, meaning, and defamiliarization to photographs, allowing users to construct a mental distance in images that deviates from everyday experiences. We offer insights into the psychology of visual styles and implications for designing filter apps and photo-sharing platforms.

## Author Keywords

Digital filter; construal level theory; visual style; mobile app; computational text analysis

## ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

## INTRODUCTION

Today's visual culture is characterized by the widespread use of digital photo filters. With filter apps like Instagram or VSCOcam, users can easily apply interesting effects to their pictures, for example, simulating the look of analogue photography or transforming a picture into a sketch (Figure 1). It is estimated that about half of the photos uploaded to
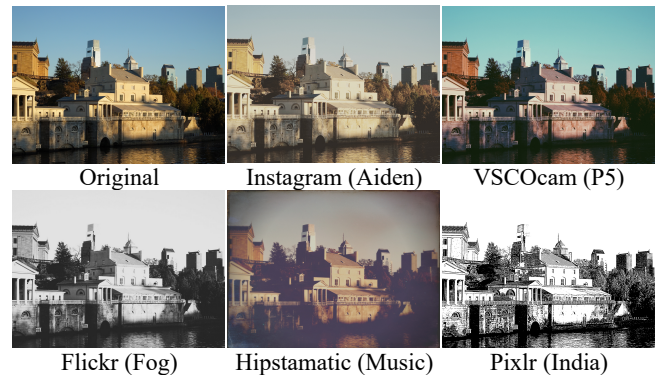
**Figure 1. Photos processed by different mobile filter apps, with specific filter names in brackets.**

Instagram have been processed by one of its retro filters [30]. According to a parenting website, millennial parents are even naming their babies after Instagram filters [5].

As a technological innovation and a cultural phenomenon, the photo filter has invited a lot of discussion in the media [2, 9, 14]. Some have celebrated that filter apps provide ordinary users with convenient ways of exercising creativity and producing shareable images, while others have questioned whether the prevalence of photo filters encourages the visual sameness in photography or harms the credibility in photography by adding a fake layer of history and sentiment to pictures [2, 9, 14]. Despite the HCI's community's long-standing interest in photographic practices (e.g., [29]), not many studies have empirically tested the effects of photo filters. A few existing studies have so far mainly focused on filters' aesthetical appeal or users' motivations to use filters [6, 31, 35]. Some important aspects of the digital filter, for instance, its resemblance to analogue photography and its link to nostalgic consumption, are noticeably understudied.

Drawing inspiration from photography, psychology and art theories, we conducted a pioneering experimental study and investigated the impacts of photo filters from multiple perspectives. First, we propose that digital photo filters, by imitating the look of analogue photography and distorting the original color in photographs, can defamiliarize our experiences of ordinary objects and increase viewers' psychological distances to images. In addition, we use computational text analysis to compare viewers'

descriptions of different versions of photos and argue that the use of photo filters can increase viewers' construal levels, leading them to perceive images more abstractly and interpretatively. At last, this study also takes participants' individual differences into account and question if they moderate filters' effects. In sum, this study provides fresh insights into the psychology of the digital filter, a popular feature of today's social media design, and offers implications for designing future photo-editing and photo-sharing technologies.

## RELEVANT WORK

### Aesthetic appeal

Previous research on the effects of photo filters has mainly focused on aesthetical appeal and visual engagement. Given the popularity of filters, one may simply assume that photo filters should make a picture more attractive. Users have expressed that filters allow them to improve the aesthetic quality of photos, adjust contrast, exposure or color, and make photos look fun and unique [6, 31]. However, people may prefer the original photo under certain circumstances: For example, the original photo is of good quality or the filter is so bold that it may distract viewers from the photo itself [6]. The hashtag #nofilter has also gained popularity on Instagram, signaling a user's claim that the accompanying photo has not been processed by filters [2].

Empirical studies have so far reached no decisive conclusions regarding filters' visual appeal. One study that experimentally examined the effects of three popular Instagram filters—Earlybird, Hefe, XProII—on people's aesthetical ratings of photographs found that people actually preferred unfiltered photos over filtered versions [35]. Another experiment that investigated non-photorealistic rendering—which transformed photographs into stylized paintings—showed that this technique actually had detrimental effects by reducing viewers' emotional responses to images and producing more confusion and distraction [32]. However, an analysis of Flickr photos revealed that filtered photos were 21% more likely to be viewed and 45% more likely to be commented on by viewers [6]. Specifically, filters that increased warmth, exposure or contrast, as well as those creating a vintage effect, made photographs more attractive to users. In contrast, filters that produced photographic artifacts or loss of highlight details were less engaging [6]. Given the inconsistency in previous studies, we propose a research question whether filtering photos impacts their visual appeal in this study.

### RQ1: How does the use of photo filters impact the visual appeal of photographs?

### Defamiliarization

The photo filter is not just an aesthetic tool; it also distorts the depicted reality in photographs. Some scholars argued that with filter apps users could create random and serendipitous effects in their photos, and aestheticize the imperfections embedded in analogue-look filters, thus countering the flawlessness of digital photography [12]. A comparative analysis of Instagram users and analogue photographers showed both groups used these technologies to escape from the stark reality created by digital cameras, and to give meanings and celebration to their daily experiences [31].

Such findings echo with some art theorists' claim that the defamiliarization of ordinary objects plays an important role in the production of art [38]. By presenting common things in an unusual way, the technique of defamiliarization primes viewers to pause and wonder at objects that are otherwise taken for granted, producing an artistic experience of the routinely seen. As Susan Sontag put, "the photographer is always trying to colonize new experiences or find new ways to look at familiar subjects—to fight against boredom" [40]. From this perspective, the photo filter more than changes photographs' look; it provides users with convenient and fun ways to distance their pictures from the reality as well as to elevate otherwise mundane moments.

### Construal level theory

As analogue photo filters resemble an aesthetic from the past and create a deviance from the reality in photographs, a theory that particularly deals with our perceptions of distance—construal level theory (CLT)—should be relevant here. Psychologists and HCI researchers have applied the framework of CLT to study the impacts of various visual media, such as images versus words [4], teleconference [23], 3D panoramas [27], and virtual immersive environment [1]. Different communication mediums can effectively change our perceptions of distance and consequently how we think about things.

As CLT posits, the way an individual perceives an object or an event is influenced by psychological distance, which specifies how far away one feels the stimuli is from the here, now and the self. Objects or events are perceived in four dimensions of psychological distance: temporal (now vs. past or future), spatial (here vs. remote locations), social (self vs. others), and hypothetical (reality vs. counterfactual or unlikely events) [25, 44].

CLT posits that psychological distances impact how we see things. For events or objects at the far end of psychological distances, we think about them in abstract ways (high construal level). In contrast, for things at the near end of psychological distances, we perceive them in a more concrete and detailed way (low construal level). In addition, changing construal level can also influence people's perceptions of psychological distances. For example, thinking about actions in an abstract instead of a concrete way leads people to estimate the actions would happen in the more distant future [24].

### Color vs. black-and-white

Research has shown that B&W and color photography

impact our perceptions of content in different ways [19, 21, 22, 41]. Particularly, previous research has shown that B&W photography is linked to more abstract, superordinate construal, while color photography is associated with more concrete, detail-oriented construal [21], which may offer us some insights into the effects of photo filters. The link between monochrome imagery and high construal level may have several explanations.

First, B&W photography completely removes the color from the original photos, creating a monochrome world that is not familiar to the naked eye [21]. The loss of color and the defamiliarization of the depicted objects in B&W photographs can make it more difficult for viewers to recognize and process the content in the photographs [22, 41]. Meanwhile, as people generally associate distant objects with difficulties to observe and apprehend, cognitive disfluency can increase psychological distance and construal level. For instance, subjects assigned to a questionnaire printed in an illegible font wrote more abstract answers than those seeing an easily readable font [3]. Therefore, by raising the level of disfluency, B&W photography is able to increase viewers' construal level.

The temporality embedded in B&W imagery may also account for the increase in psychological distance. Since color photography replaced B&W photography as the prevailing form of photography around the 1960s–1970s, people may associate monochrome imagery with a more distant past. Movies like *American History X* (1998) and *The Phantom of the Opera* have exploited the temporal connotation in B&W imagery and used it to represent the scenes that happened before the scenes in color. Photographers also argue that B&W pictures have a more timeless look than colored ones [34]. For instance, the World Press Photo of the Year 2015 was awarded to a B&W photograph, as "it's a very classical photo, and at the same time it's timeless" [47].

In addition, monochrome photos highlight the depicted objects' overall shapes and forms, while color photos facilitate attention to details and local features [21]. Compared to a B&W version, colored presentation of messages often draw people's attention to more peripheral, irrelevant and detailed information [19], reflecting low-level construal. In summary, the defamiliarization of reality, the loss of color and details, and the unique visual style associated with a certain time period, may all link B&W imagery to high construal level.

### Photo filters and construal levels
Similar to the effects of monochrome imagery, analogue photo filters may also increase psychological distance and construal level by distorting the original photographs and creating a visual style that deviates from the reality. Without the aid of original colors, people might need additional efforts to retrieve and process the messages conveyed in filtered photographs. In addition, different aesthetic styles of photography are often linked to different

time periods. The transition from film photography to digital photography happened around the 1990s and 2000s [26]. Studies also linked the use of photo filter apps to a nostalgic desire to connect with the past [12, 31]. Therefore, we should expect that filters that imitate certain historical styles of photography should influence how viewers construct the temporal distance of photographs.

**H1: Compared to the original version, the use of B&W and film-style photo filters increases viewers' perceptions of temporal distance to photos.**

As CLT posits, people experience different psychological distances—whether it is temporal, spatial, interpersonal or hypothetical—through similar mental mechanisms [7, 44]. Things perceived as distant or close in one dimension are also likely to be perceived similarly in other dimensions. If photo filters can increase perceived temporal distance, this effect should also extend to perceived spatial distance.

**H2: Compared to the original version, the use of B&W and film-style photo filters increases viewers' perceptions of spatial distance to photos.**

Construal level also impacts how people construct and describe events or objects. People tend to use more abstract and interpretative language to describe people or events that are psychologically far away [15, 25]. Based on previous research, we expect that different construal levels should be reflected in the following linguistic features:

*Articles and numbers*. Articles (e.g., "a," "the") are often used to refer to concrete objects or events, and numbers are used to specify the quantity. These two features may signal a high level of linguistic concreteness [33]. In one study, articles and numbers negatively correlated with the level of interpretation and linguistic abstraction in participants' descriptions of photographs [8].

*Tentative words*. Linguistic abstraction is related to the level of interpretation [8]. When construal level increases, people tend to make assumptions about events, instead of describing what they directly see. In one study, when describing a place, subjects' use of tentative words positively correlated with their estimation of the physical distance of that place [27]. As photo filters may increase psychological distance and construal level, we expect that subjects use fewer articles or numbers but more tentative words (e.g., *maybe*, *perhaps*, *or*, *guess*) for filtered photographs.

**H3: Compared to the original version, viewers describe the B&W and film-style filtered photos in a more abstract and interpretative manner, which is manifested in (a) fewer articles and numbers, and (b) more tentative words.**

### Individual characteristics
At last, a few individual factors may impact how one sees and interprets photographs, moderating the impacts of photo filters. As many photo filters imitate visual styles

from certain periods, age should play a role here as people of different age cohorts may differ in their exposure to various photographic aesthetics and technologies. People from the older generations might have witnessed how photographic aesthetics changed over decades, either from B&W to color photography or from film to digital photography. The younger generations might have less memory of the history of photography while being more familiar with widely accessible photo-filtering apps that can easily change the look of photographs.

In addition, people's knowledge of photography and involvement in photography can also influence whether they can recognize the potential manipulation in photographs and how they use digital filters. In one experiment, exposure to the technique of photographic manipulation led participants to regard news images less believable [39]. Interviews of filter users suggested that casual users often applied filters to substantially change the look of their photos with bold effects and visual artifacts, whereas serious amateurs who had experiences with professional cameras and post-editing software tended to use filters to do tasks like color correction and prefer more subtle effects [6]. However, previous studies have rarely examined the roles of individual differences, so this study proposes a research question regarding the potential moderating roles of participants' age and photographic knowledge in the effects of photo filters.

**RQ2: Do viewers' age and photographic knowledge moderate the impacts of photo filters?**

### METHOD

### Participants
A total of 201 participants located in the United States were recruited from the crowdsourcing platform Amazon Mechanical Turk [11]. Some demographic characteristics of the participants were obtained, including gender (56.7% female), age ($M = 36.2$, $SD = 12.4$), and education attainment (high school graduate or less = 13.4%, some college = 27.9%, college degree = 46.8%, and postgraduate = 11.9%).

### Procedure
Participants were randomly assigned into three conditions (between-subjects): original ($N = 72$), B&W ($N = 63$) and film-style ($N = 66$). Each participant was exposed to ten photos and instructed to describe each photo as well as answer several questions about it. One subject in the film-style condition was removed from the dataset as he/she was repeating the same sentence in the descriptions of different photos, which resulted in a sample size of 200.

### Stimuli
Ten photographs—referred as P1–P10 in the paper—were used in the study, which covered a wide range of topics, such as war, celebrity, festival and environmental pollution. All the photos featured some people with actions and a moderate amount of details so viewers could potentially



**Figure 2. Examples of photos across three conditions.**

engage in some levels of interpretations about these people's intentions or behaviors. These photos were also linked to some kind of event or remote places since participants were asked to estimate when and where the photo was taken in the study. All the photos were cropped and displayed in the same size (width 730px, ratio 3:2). Photos were processed with two filters (B1 and P8) from the mobile photo-editing app VSCOcam, which gave them a B&W, or a film-style, instant Polaroid look, respectively. Figure 2 illustrates how the same photo differs across the three conditions.

### Measures
*Visual appeal*. We constructed the scale based on previous research on the interestingness of news photographs [16]. The scale had four five-point items ($\alpha = .839$): *the photo is of good quality*; *the photo draws my attention*; *the photo provokes emotions in me*; *I would like to know the story behind the photo*. Participants' ratings of the ten photographs were averaged.

*Perception of temporal distance*. On a scale from 1980 to 2016, participants indicated in which year they thought the photo was taken. Participants' perceived temporal distance was calculated by subtracting their averaged estimates of the ten photographs from 2016.

*Perception of spatial distance*. One a scale from 0 to 10000 miles, participants estimated how far away each photo was taken from where they were. To give them a reference point, participants were told that the distance between New York and San Francisco was about 2500 miles. In CLT literature, estimation of distance has been conventionally used as a proxy for psychological distance [3, 27]. Participants' estimates of the ten photographs were averaged.

*Linguistic features.* For each photo, participants were asked to describe the photo in a few sentences. In this study, we chose the software Linguistic Inquiry and Word Count (LIWC) to computationally analyze subjects' descriptions of photographs. LIWC is a program that categorizes words into psychologically meaningful categories, which has been widely used in the field of psycholinguistics [43]. Given that the average length of participants' descriptions was very short ($M$ = 21.4 words, $SD$ = 11.5), we used the averaged numbers of words belonging to the *article*, *number*, and *tentative* categories as dependent variables instead of LIWC's default metrics (percentage of words), as percentage measures tended to be unstable when divisors were small [20]. The length of participants' descriptions did not significantly vary by condition, $F(2, 197) = 0.91$, n.s.

*Photographic knowledge.* On five-point scales ranging from *no understanding* to *full understanding* (α = .942), participants indicated how familiar they were with the following terms: *exposure, aperture, white balance, depth of field* and *HDR* ($M$ = 2.50, $SD$ = 1.12).

**ANALYSIS AND RESULTS**
For R1, H1, H2, and H3, we conducted a series of ANOVA tests and planned contrasts that compared the means of the two filtered conditions to the original condition. Table 1 provides the correlations among the dependent variables examined in the study.

**Impacts on visual appeal**
RQ1 asked whether the photo filters influenced photographs' visual appeal. There were no significant differences among the three conditions, $F(2, 197) = 1.69$, n.s. (Figure 3a). Additional planned contrasts, however, indicated that film-style filter might decrease photographs' visual appeal, though this trend was only approaching statistical significance, $p = .068$, Cohen's $d = 0.33$.

**Impacts on psychological distances**
H1 predicted that the B&W and the film-style filters increased viewers' perceptions of temporal distance, which was supported by the results (Figure 3b). There were significant differences among the three conditions in terms of participants' average estimation of temporal distances, $F(2, 197) = 30.74$, $p < .001$, partial η² = .238. According to participants' estimates, B&W and film-style filtered pictures were taken 5.90 ($p < .001$, $d = 1.31$) and 3.60 years ($p < .001$, $d = 0.86$) earlier on average than the original version.

H2 predicted that the two photo filters impacted people's perceptions of spatial distance, which was not supported by the results. No significant differences were found, $F(2, 197) = 0.79$, n.s. (Figure 3c).

**Impacts on LWIC linguistic features**
H3 looked at how different photo filters impacted the linguistic features of people's textual descriptions of the photographs. In terms of articles and numbers (H3a), ANOVA tests and planned comparisons showed no

| | temporal distance | spatial distance | article | number | tentative |
|---|---|---|---|---|---|
| visual appeal | −.115 | .003 | −.032 | −.073 | −.067 |
| temporal distance | | −.016 | .001 | −.041 | .024 |
| spatial distance | | | −.059 | −.084 | .001 |
| article | | | | .652*** (.064) | .599*** (−.407***) |
| number | | | | | .404*** (−.240***) |

**Table 1. Correlation matrix of dependent variables. Partial correlations among linguistic features controlled for the length of descriptions are provided in brackets. $N = 200$. ** $p < .01$, *** $p < .001$.**
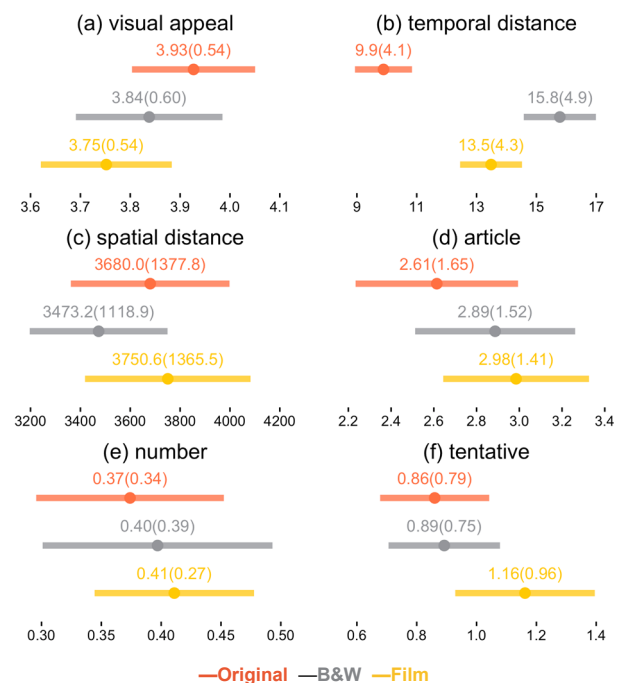


**Figure 3. Means and standard deviations in brackets for dependent variables across three conditions. Error bars represent 95% confidence intervals.**

differences, $F(2, 197) = 1.09$ and 0.21, respectively, n.s. (Figure 3d, 3e).

The differences among participants' use of tentative words (H3b) were approaching statistical significance, $F(2, 197) = 2.60$, $p = .077$, partial η² =.026. Planned contrasts revealed that the film-style filter led subjects to use 0.30 more tentative words on average in each description, which was statistically significant ($p < .05$, $d = 0.34$), but B&W filter did not have a significant effect (n.s.) (Figure 3f).

Table 2 provides some examples of participants' descriptions that differ in the use of tentative words. Under low construal levels, subjects described the photo in

| Photo | Low tentative | High tentative |
|---|---|---|
| P1 | A group of children smile up at the camera with their hands outstretched. | A group of African children. They <u>appear</u> rather healthy and vibrant. It <u>appears</u> that they are playing a game, <u>most likely</u> football with a home made ball. |
| P2 | A new born baby is being weighed, checked, and wrapped. In comparison to everybody in the picture's hands then the baby is extremely small. | This is a baby is <u>some</u> sort of trauma. It <u>may</u> have been born prematurely or the mother <u>may</u> be hurt in <u>some</u> way. Doctors are <u>trying</u> to help the baby. |
| P4 | An American soldier is giving water to a young girl. The girl has a number 2 on her forehead. | The little girl is a survivor from <u>some</u> <u>sort</u> of traumatic event <u>or</u> natural disaster. It is very endearing to see the soldier comforting her and taking care of her. |
| P6 | A helicopter has just dropped of US troops in the desert. The solder's form a circle on the ground with their guns drawn pointing outwards. Their packs besides them. | Looks like location is <u>somewhere</u> in the desert, <u>possibly</u> middle east. Soldiers are defending a landing zone for <u>possible</u> evacuation. |
| P7 | This is a man holding a small turtle above a fishing net. The man is wearing a dirty white outfit and the sleeves are duck taped shut. He is standing on a boat with this turtle. | An oil covered turtle being held by a worker in a white coverall. This <u>seems</u> to be part of an environmental recovery and rescue attempt, <u>probably</u> after <u>some</u> kind of oil spill. |

**Table 2. Examples of participants' descriptions differing in the use of tentative words (underscored).**

|  | visual appeal | temporal distance | spatial distance | article | number | tentative |
|---|---|---|---|---|---|---|
| B&W | .026 | .439*** | −.093 | .042 | −.001 | −.084 |
| film | −.153+ | .060 | .067 | .088 | .052 | .205* |
| age | .162* | −.192** | .039 | .055 | −.073 | .061 |
| PK | .211** | −.016 | .074 | −.119 | −.089 | −.183* |
| age×B&W | .025 | .088 | .040 | .023 | −.051 | −.139 |
| age×film | −.139+ | −.136+ | −.095 | −.063 | .055 | .079 |
| PK×B&W | −.077 | −.111 | .008 | −.062 | .032 | −.173* |
| PK×film | .145+ | .026 | −.006 | .134 | −.007 | .108 |

**Table 3. Regression analysis with interaction effects between individual characteristics and experimental conditions. Standardized coefficients are shown. PK = photographic knowledge. $^+ p < .10,$ $^* p < .05,$ $^{**} p < .01,$ $^{**} p < .001.$**



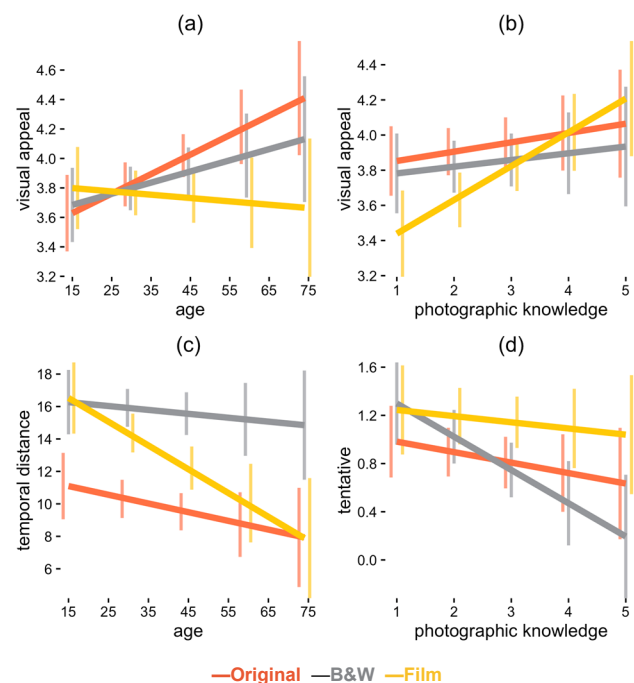**Figure 4. Interactions between individual characteristics and experimental conditions. Error bars represent 95% confidence intervals.**

concrete details and used few tentative words. In contrast, subjects under high construal levels made inferences or hypotheses about the situation and people's intention, which led to an increase in tentative words (e.g., *or*, *some*, *possibly*).

### Individual characteristics

RQ2 asked whether individual characteristics moderated the impacts of photo filters. We used a regression-based approach to better detect the interactions between categorical and continuous variables while retaining the moderators' effects on the outcomes [46]. Using effect coding, the analysis treated the original condition as the reference level and recoded the other two conditions as B&W (original = −1, B&W = 1, film = 0) and film (original = −1, B&W = 0, film = 1). We created four interaction terms that multiplied moderators (mean-centered) by experimental conditions.

As summarized in Table 3, one interaction term (photographic knowledge × B&W) was significant ($\beta = -.173, p < .05$) in predicting linguistic tentativeness, while three interaction terms were approaching statistical significance—age × film ($\beta = -.139, p = .095$) and photographic knowledge × film ($\beta = .145, p = .087$) in predicting visual appeal, and age × film in predicting temporal distance ($\beta = -.136, p = .067$).

We further illustrated the interaction patterns in Figure 4. Both age ($\beta$ = .162, $p$ < .05) and photographic knowledge ($\beta$ = .211, $p$ < .01) had positive impacts on visual appeal. However, while the younger generation found different versions of photographs equally appealing, the film-style filter decreased photos' visual appeal for older viewers (Figure 4a). In addition, while viewers who were knowledgeable about photography liked all three versions, less knowledgeable participants particularly found the analogue-style photographs unappealing (Figure 4b). Age also decreased perceived temporal distance ($\beta$ = −.192, $p$ < .01). The B&W filter increased perceived temporal distance among participants across all age groups, but the use of film-style filter only impacted the younger participants (Figure 4c). At last, the more knowledgeable about photography people were, the less tentative they were in the descriptions ($\beta$ = −.183, $p$ < .01). This trend was most prominent in the B&W condition (Figure 4d).

**Post-hoc analysis of linguistic features**

As an exploratory step, we also applied a text mining technique to investigate other potential ways of how photo filters might impact participants' language use—specifically, what linguistic features could best differentiate the three experimental conditions. The analysis used participants' descriptions as text input and the three experiment conditions as the labels to be predicted. We then extracted terms that had the strongest correlations with each condition—in other words, terms subjects used disproportionately more in one condition versus the other two [28]. Given the effects of photo filters are not widely examined in previous research, this data-driven approach in linguistic analysis—sometimes referred as the "open-vocabulary approach"—should generate new insights that might not be captured by pre-defined word categories and present a more comprehensive picture of digital filters' effects, providing directions for future research [37].

Figure 5 summarizes the results for each photograph. We only looked at unigrams (single words) that appeared at least 5 times in the descriptions. We also retained all the words that passed the significance test of $p$ < 0.05 without further adjusting $p$-levels. It is important to acknowledge that this section of analysis is exploratory and might produce spurious positives. Other studies that adopt a similar approach often use a more stringent significance level corrected for the number of features examined (e.g., [37]). However, compared to those studies using big data, this study had an extremely small dataset ($N$ = 200), and doing so would substantially reduce our power to detect potential differences. Future studies are needed to corroborate the following interpretations.

Based on the analysis, we can notice several trends:

*Tentativeness.* Consistent with our previous findings, participants used more words that indicate tentativeness for analogue-style filtered images, including P1 (*probably*, *seems*, *or*), P2 (*perhaps*, *appears*, *maybe*), P4 (*sort*), P5
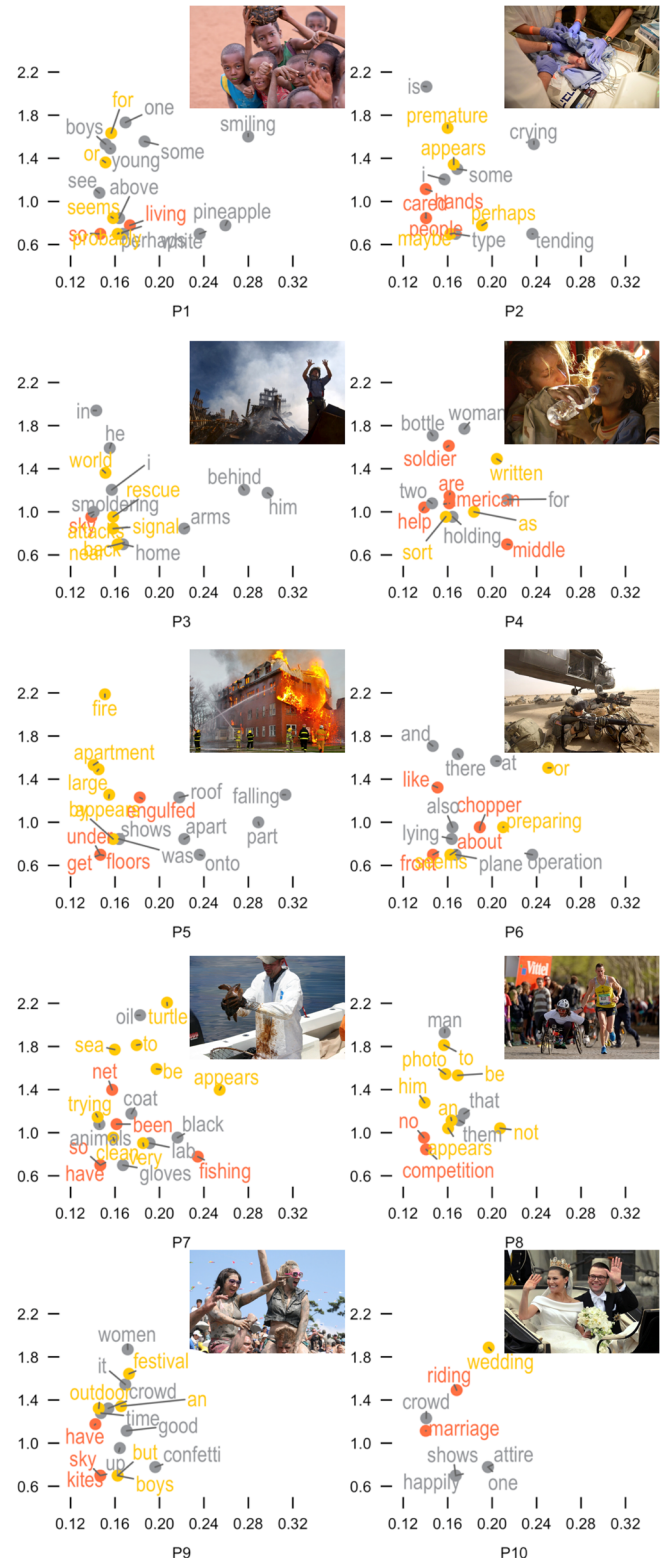


**Figure 5. Terms used by participants that best differentiate the three conditions (** original **,** B&W, **and** film **) in each photo. Horizontal axes represent correlation coefficients and vertical axes represent log-transformed frequencies.**

Credit: P1, IamNotUnique/Flickr; P2, Israel Defense Forces/Flickr; P5, Sylvain Pedneault/Wikipedia; P7, NOAA; P8, Marie-Lan Nguyen/Wikipedia; P9, Stinkie Pinkie/Flickr; P10, Holger Motzkau/Wikipedia; Others in Public domain.

(*appears*), P6 (*or*, *seems*), P7 (*appears*, *trying*), and P8 (*appears*). B&W filter also led participants to use more tentative words in P1 (*some*, *perhaps*) and P2 (*some*). Interestingly, participants also used more "I" when describing P2 and P3. Further inspection of participants' use of first-person pronouns suggested that this often signaled expressing personal interpretations (e.g., "I am guessing…," "I presume…," "I think…") or uncertainty (e.g., "I cannot tell if…," "I could be wrong…") in the sample. These trends corroborated the claim that the use of photo filters might lead to tentativeness and analytic thinking, indicating an increase in construal level.

*Accuracy*. The use of B&W photo filter might lead subjects to incorrectly identify the objects in pictures. For example, in P1, subjects in the B&W condition were more likely to say that one child was holding a *pineapple*, though the object was actually a handmade ball. In P6, subjects tended to see the helicopter as a *plane* in the B&W version, instead of a *chopper* in the original version. In P9, participants tended to see the small objects flying in the sky as *confetti*, but they were actually *kites*, noted by viewers who saw the unfiltered version. This trend seemed to indicate that by removing the original color in photos, B&W filters might make it more difficult for viewers to recognize the content in images, which could lead to more errors.

*Details*. Subjects seeing the original version seemed to be more likely to mention details in the background or objects in the periphery. For example, subjects noticed a *fishing net* shown at the bottom of P7, the *kites* flying in the background in P7, and mentioned the *sky* more in P3 and P9. They also noted that the person on the left in P4 was an *American soldier*—possibly due to the mark on her clothes—while participants in the B&W condition simply referred her as a *woman*. Meanwhile, B&W pictures seemed to highlight the contrast between black and white regions, making objects that were originally in black or white more prominent to viewers. For example, participants in the B&W condition tended to point out the white *lab coat* and black *gloves* in P7, and the B&W wedding *attire* in P10. Participants also seemed to pay more attention to the people in B&W photographs, as they mentioned more the *young boys* in P1, the *woman* in P4, the *man* in P8, and the *women* in P9—though this might also due to people in B&W used more vague and abstract terms to refer to people.

*Emotion*. Participants were more likely to mention the emotional expression in B&W photographs. They were more inclined to say that the children were *smiling* in P1, the baby was *crying* in P2, the girls were having a *good time*, and the couple were behaving *happily* in P10. This observation seemed to echo with some photographers' claim that B&W could accentuate emotional expressions in photographs [34].

## DISCUSSION

With the wide availability of camera phones and online photo-sharing platforms, more and more people are practicing photography. A variety of photo filter apps have also changed the way of photo-editing, providing average users with easy and fun ways of reworking their photos. This work probes into this technocultural phenomenon and demonstrates how the use of photo filters could shape our perceptions and interpretations of images. The findings have implications in multiple aspects.

### Understanding affordances of photo filters

Available HCI studies on the effects of photo filters have so far mainly focused on visual engagement and yielded contradictory results [6, 32, 35]. In this study, the film-style filter might actually decrease visual appeal, though this effect did not reach the conventional level of statistical significance. In addition, this research brought the concepts of defamiliarization and psychological distance into our understanding of visual styles. People found both B&W and film-style filtered photographs more distant than unfiltered ones on the temporal dimension, and the effect sizes were quite large. People also used more tentative words when describing film-style filtered images—which appeared as a medium-size effect—indicating an increase in personal interpretation and construal levels.

The post-hoc analysis of linguistic features not only corroborated the finding that using the digital filter increased linguistic tentativeness but also provided some new insights. Particularly, the use of B&W filters might highlight the emotional expressions in photos but make it more difficult for viewers to correctly identify the objects, while unfiltered photos made participants notice more background details that might be easily ignored in filtered versions. These findings seemed to suggest that photo filters did increase construal levels by decreasing cognitive fluency and shifting viewers' attention from local details to global themes in pictures. Nevertheless, future studies are needed to further examine these claims generated from the exploratory analysis.

The two filters studied also had distinct effects. Compared to the film-style filter, the B&W filter evoked a stronger sense of past but failed to statistically significantly influence visual appeal or linguistic tentativeness. Interestingly, the trend that photographic literacy decreased tentativeness was most salient in the B&W condition (Figure 4d). This might be due to that B&W photography has been long and commonly practiced among amateur photographers—especially in documentary photography and portrait photography [14, 34, 47]—thus not being seen as a novel or unfamiliar visual style by photographically knowledgeable participants. While the B&W filter substantially distorts the look of a photo by completely removing its color, it might have less defamiliarization effect to provoke higher levels of mental construal than the film-style filter.

In combination, this study highlights filters' potential multi-sided effects. A visually unfamiliar filter might make an image more difficult to process and less appealing.

However, the digital filter may also defamiliarize objects that are often seen as banal and commonplace, and help users construct a temporal distance in their photos. The defamiliarization might also provoke mental activities of high construal levels, such as imagination, contemplation, and interpretation, which are essential in creating artistic experiences.

**Design photo filters and visual interfaces**
This study indicates that digital filter is more than an aesthetical tool and app designers might construct different filters that fulfill certain purposes. For users who want to distance their photos from the reality, designers might provide a visually unfamiliar filter that imitates the look of analogue photography—like the one used in this study—to evoke a sense of time as well as more contemplation and analytic thinking among viewers. For users who want to candidly record the moments they capture in photos, designers might provide filters that do not substantially distort the original look of photos.

When designing visual aesthetics, practitioners should also take the characteristics of the users into account. For example, in the results, the analogue-look filter was not popular among people who were older and who had less knowledge about photography, while the younger generation and more knowledgeable viewers appreciated filtered and unfiltered versions almost equally (Figure 4). Therefore, photo-editing apps might be improved by being tailored to different types of users. For example, social media apps like Instagram might change their default order of photo filters for different people and recommend certain filters to users that they might most appeal to.

It might also be interesting to design features that allow users to preview the potential effects of applying different filters before they publish their photos to online social networks. For example, the linguistic analysis in the study implies that textual data like comments on photographs can be a rich source of discovering potential patterns of digital filters' effects. One might use the huge amount of social media data or findings from crowdsourcing experiments like this study to develop algorithms that can reliably predict the social feedbacks a photo might receive if processed by one particular filter. As some computer vision works have already started to use computationally calculated visual features to predict images' popularity and users' emotional status [36, 45], this should be a promising direction for future research and design.

The HCI community has also been interested in how to better visualize temporal data in different interfaces (e.g., [17]). This study suggested that the impacts of digital filters on perceived temporal distances were quite prominent. Therefore, it might be possible for designers to use different filters to visualize temporal data while simultaneously producing the psychological feelings of time. For example, in a newsfeed that predominantly features images and videos, using photo filters might be an easy way to effectively convey temporal information to viewers. Additionally, future studies might also examine what exact visual components of photo filters—for example, a change in saturation or a warm hue—that contribute to their effects on our perceptions of images and see if these effects also extend to abstract color schemes or visual artifacts that can be more widely applied in design.

The results may also indicate that some levels of distortion and defamiliarization in visual communication design might be valuable as they can reshape users' experiences of the familiar and the ordinary. As previous research has indicated, people take photos not only to document moments of their lives and share them within their social networks but also to elevate these special moments from their everyday experiences [18, 29]. Filter apps might allow users to add an additional layer to the documented, to rework the present as a potential past, and to distance their pictures from the mundane and the realistic. Future research may wish to examine how visual styles might impact our involvement with other types of visual media, such as videos and virtual environments.

**Construal level theory and application**
This study also contributes to our understanding of CLT. The use of B&W and film-style indeed increased perceived temporal distance, though the effect did not extend to the spatial dimension as hypothesized. The correlation between perceived temporal distance and spatial distance was also not statistically significant (Table 1), which seemed to contradict CLT's claim that all psychological distances are correlated. One explanation might be that the heterogeneity in participants' locations might add too much statistical noise to the analysis. Based on IP addresses, additional analysis that only included participants located in the contiguous United States ($N = 193$) and controlled for their states and geographic coordinates, however, still revealed no significant differences. Another explanation might be that participants were unable to translate psychologically felt distances to estimates of concrete numbers. Nevertheless, some previous research did point out that priming distance on the temporal dimension did not always influence people's perception of spatial distance, arguing that the spatial dimension is more primary than the temporal one [10, 48]. Further studies may use participants located in one location and photos of the same location— for instance, a famous landmark—with more subjective measures of spatial distance to see if filters impact perceptions of spatial distance.

Future studies can also examine the exact mechanism of how an analogue-style filter shapes people's interpretation of photographs. In this study, subjects' perceived temporal distance did not correlate with the linguistic features in their description (Table 1), which seemed to indicate that it was not the temporal distance that mediated the impacts of visual styles on viewers' construal levels. Thus, other mechanisms, such as color distortion, cognitive disfluency,

and defamiliarization might play a role in the process, which suggests arenas for future research. In addition, the number of tentative words used did negatively correlate with the number of articles ($r = -.407$, $p < .001$) and numbers ($r = -.240$, $p < .001$) used, when the average length of descriptions was controlled for (Table 1). This seems to suggest that the use of articles and numbers could still signal higher certainty and lower construal level, but was not sensitive enough to reveal the effects of photo filters on language use in this study.

As psychological distance and construal level can shape people's attitudes and behaviors, the HCI community has been increasingly interested in applying CLT in designing persuasive messages and technologies (e.g., [42]). An increase in construal level can lead people to focus on more primary features of objects, think about actions in terms of goals instead of means, and interpret people's behaviors based on dispositions rather than specific situations [25]. Therefore, we can also use different visual styles to effectively change how people perceive things and their subsequent attitudes and behaviors. In an experiment, the use of B&W photography led people to focus more on the primary function of a product rather than its secondary features [21]. The photo filter might serve as a convenient tool for us to engineer attitudinal and behavioral changes via changing construal level.

### Limitations
The current study has several limitations. First, only ten photos were used in the study and the photos chosen might be too specific to represent all genres of photographs. Future studies can further our investigation by looking at other categories of images, such as landscape, portrait and food. In addition, the photos used in the study were generally of good quality: viewers gave them an average rating of 3.84 on a 5-point scale of visual appeal. Future research may examine how filters impact more amateurish, technically flawed or low-quality pictures. The effects of photo filters might not be consistent across different kinds of photos. Future studies might also wish to look into the potential moderating roles of photos' characteristics.

As many images are viewed, edited and circulated on mobile screens these days, future studies might wish to ask participants to view photographs on mobile phones instead of computers. Previous research suggests that different photo sizes can impact people's aesthetical evaluation of photographs [13], and it would be interesting to see if the screen size moderates the impacts of filters. We also used between-subjects design in this experiment in order to prevent subjects from recognizing the presence of filters and consequently adjusting their answers. But this strategy might not fully simulate users' experience of picking up one filter from multiple options on their mobile apps, and future research can also explore this direction.

At last, the study only examined two filters in this study. In addition to distorting colors, mobile filters can also change the photograph by adding grains, scratches, vignette, frames and light leaks, or even transforming it into a painting (Figure 1). Given the diversity in today's photo filters, future studies might further investigate the effects of other types of filters as well as different components of filters.

### CONCLUSION
We examine how the widely used photo filters impact people's perceptions and interpretations of photographs, inspired by defamiliarization theory and construal level theory. We showed that the use of two photo filters—one B&W and one analogue-style—substantially increased viewers' perceived temporal distances to photographs, but not spatial distance. Subjects also tended to describe analogue-style filtered photos more interpretively and tentatively than unfiltered ones, indicating an increase in construal level. Individual characteristics like age and photographic knowledge moderated the impacts of filters. We offer insights into visual styles, photographic practices and construal level theory, and provide implications for designing photo filters and visual interfaces.

### REFERENCES
1. Ahn, S. J. 2015. Incorporating immersive virtual environments in health promotion campaigns: A construal level theory approach. *Health Communication* 30, 6: 545–556.

2. Alper, M. 2014. War on Instagram: Framing conflict photojournalism with mobile photography apps. *New Media & Society* 16, 8: 1233–1248.

3. Alter, A. L. and Oppenheimer, D. M. 2008. Effects of fluency on psychological distance and mental construal (or why New York is a large city, but *New York* is a civilized jungle). *Psychological Science* 19, 2: 161–167.

4. Amit, E., Algom, D., and Trope, Y. 2009. Distance-dependent processing of pictures and words. *Journal of Experimental Psychology: General* 138, 3: 400–415.

5. BabyCenter. 2015. Hottest baby name trends of 2015. Online article. (December 2015). Retrieved May 2, 2016 from: http://www.babycenter.com/0_hottest-baby-name-trends-of-2015_10408983.bc

6. Bakhshi, S., Shamma, D. A., Kennedy, L., and Gilbert, E. 2015. Why we filter our photos and how it impacts engagement. In *Proceedings of the International AAAI Conference on Web and Social Media* (ICWSM '15), 12–21.

7. Bar-Anan, Y., Liberman, N., and Trope, Y. 2006. The association between psychological distance and construal level: Evidence from an implicit association test. *Journal of Experimental Psychology: General* 135, 4: 609–622.

8. Beukeboom, C. J., Tanis, M., and Vermeulen, I. E. 2013. The language of extraversion: Extraverted people talk more abstractly, introverts are more concrete.

*Journal of Language and Social Psychology* 32, 2: 191–201.

9. Bevan, K. 2012. Instagram is debasing real photography. Online article. (19 July 2012). Retrieved December 1, 2015 from: http://www.theguardian.com/technology/2012/jul/19/instagram-debasing-real-photography

10. Boroditsky, L. 2000. Metaphoric structuring: Understanding time through spatial metaphors. *Cognition* 75, 1: 1–28.

11. Buhrmester, M., Kwang, T., and Gosling, S. D. 2011. Amazon's Mechanical Turk: A new source of inexpensive, yet high-quality, data?. *Perspectives on Psychological Science* 6, 1: 3–5.

12. Chandler, L., and Livingston, D. 2012. Reframing the Authentic: photography, mobile technologies and the visual language of digital imperfection. In *Proceedings of the Global Conference, Visual Literacies: Exploring Critical Issues*, 1–15.

13. Chu, W. T., Chen, Y. K., and Chen, K. T. 2013. Size does matter: How image size affects aesthetic perception? In *Proceedings of the ACM International Conference on Multimedia*, 53–62.

14. Estrin, J. 2012. Ben Lowy: Virtually unfiltered. Online article. (2 May 2012). Retrieved May 2, 2016 from http://lens.blogs.nytimes.com/2012/05/02/ben-lowy-virtually-unfiltered/

15. Fujita, K., Henderson, M. D., Eng, J., Trope, Y., & Liberman, N. 2006. Spatial distance and mental construal of social events. *Psychological Science* 17, 4: 278–282.

16. Halonen, R. 2014. *From Photographers to Viewers– What Makes Editorial Photos Interesting?*. Licentiate thesis. Aalto University, Espoo, Finland.

17. Heer, J., Kong, N., and Agrawala, M. (2009). Sizing the horizon: the effects of chart size and layering on the graphical perception of time series visualizations. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '09), 1303–1312.

18. Ito, M., and Okabe, D. 2003. Camera phones changing the definition of picture-worthy. *Japan Media Review*, August 29, 2003.

19. Katzman, N., and Nyenhuis, J. (1972). Color vs. black-and-white effects on learning, opinion, and attention. *AV Communication Review* 20, 1: 16–28.

20. Kim, H. S. 2015. Attracting views and going viral: how message features and news-sharing channels affect health news diffusion. *Journal of Communication*, 65, 3: 512–534.

21. Lee, H., Deng, X., Unnava, H. R., and Fujita, K. 2014.

Monochrome forests and colorful trees: The effect of black-and-white versus color imagery on construal level. *Journal of Consumer Research* 41, 4: 1015–1032.

22. Lee, K. J. and Perrett, D. 1997. Presentation-time measures of the effects of manipulations in colour space on discrimination of famous faces. *Perception* 26, 6: 733–752.

23. Lee, M. K., Fruchter, N and Dabbish, L. 2015. Making decisions from a distance: the impact of technological mediation on riskiness and dehumanization. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work & Social Computing* (CSCW '15), 1576–1589.

24. Liberman, N., Trope, Y., McCrea, S. M., and Sherman, S. J. 2007. The effect of level of construal on the temporal distance of activity enactment. *Journal of Experimental Social Psychology* 43, 1: 143–149.

25. Liberman, N., and Trope, Y. 2008. The psychology of transcending the here and now. *Science* 322, 5905: 1201–1205.

26. Lucas, H. C., and Goh, J. M. 2009. Disruptive technology: How Kodak missed the digital photography revolution. *The Journal of Strategic Information Systems* 18, 1: 46–55.

27. Marlow, J., and Dabbish, L. 2014. When is a picture not worth a thousand words? The psychological effects of mediated exposure to a remote location. *Computers in Human Behavior* 30, 824–831.

28. Mayfield, E., and Rosé, C. P. 2012. LightSIDE: Text mining and machine learning user's manual. Manual. (Spring 2012). Retrieved from http://www.cs.cmu.edu/~emayfiel/LightSIDE.pdf

29. Miller, A. D., and Edwards, W. K. (2007). Give and take: a study of consumer photo-sharing culture and practice. In *Proceedings of the SIGCHI conference on Human factors in Computing Systems* (CHI '07), 347–356.

30. Miller, J. 2013. What your Instagram filter says about you. Infographic. (19 March 2013). Retrieved May 4, 2016 from http://blog.marketo.com/2013/03/what-your-instagram-filter-says-about-you-infographic.html

31. Morlot, E. 2013. *Nostalgic Consumption Behaviours among Young Generations in Photography: A Comparative Approach of Instagram and Analogue Photography*. Master thesis. Umeå University, Umeå, Sweden.

32. Mould, D., Mandryk, R. L., and Li, H. 2012. Emotional response and visual attention to non-photorealistic images. *Computers & Graphics*, 36, 6: 658–672.

33. Pennebaker, J. W., and King, L. A. 1999. Linguistic styles: language use as an individual difference.

*Journal of Personality and Social Psychology* 77, 6: 1296–1312.

34. Price, N. Undated. Color vs black and white photography—What makes sense and when? Retrieved May 10, 2016 from http://www.photographyvox.com/a/color-vs-black-and-white-photography/

35. Redi, J., and Povoa I. 2014. Crowdsourcing for rating image aesthetic appeal: Better a paid or a volunteer crowd? In *Proceedings of the International ACM Workshop on Crowdsourcing for Multimedia*, 25–30.

36. Reece, A. G., and Danforth, C. M. 2016. Instagram photos reveal predictive markers of depression. Online manuscript. (13 August 2016). Retrieve September 1, 2016 from http://arxiv.org/abs/1608.03282

37. Schwartz, H. A., Eichstaedt, J. C., Kern, M. L., Dziurzynski, L., Ramones, S. M., Agrawal, M., ... and Ungar, L. H. 2013. Personality, gender, and age in the language of social media: The open-vocabulary approach. *PLOS ONE*, 8, 9: e73791.

38. Shklovsky, V. 1965. Art as technique. In *Russian Formalist Criticism*, Lemon, L. T., and Reis, M. J. (eds.). University of Nebraska Press, Lincoln, NE, 3–24.

39. Snyder, S. R. 1991. *Are Emerging Technologies Affecting the Credibility of Photographs? An Experimental Study in Photographic Believability.* Master thesis. Texas Tech University, Lubbock, TX.

40. Sontag, S. 1977. *On Photography*. Dell/Delta, New York, NY.

41. Spence, I., Wong, P., Rusan, M., and Rastegar, N. 2006.

How color enhances visual memory for natural scenes. *Psychological Science* 17, 1: 1–6.

42. Suh, M. M., and Hsieh, G. 2016. Designing for future behaviors: Understanding the effect of temporal distance on planned behaviors. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (CHI '16), 1084–1096.

43. Tausczik, Y. R. and Pennebaker, J. W. 2010. The psychological meaning of words: LIWC and computerized text analysis methods. *Journal of Language and Social Psychology* 29, 1: 24–54.

44. Trope, Y. and Liberman, N. 2010. Construal-level theory of psychological distance. *Psychological Review* 117, 2: 440–463.

45. Totti, L. C., Costa, F. A., Avila, S., Valle, E., Meira Jr, W., & Almeida, V. 2014. The impact of visual attributes on online image diffusion. In *Proceedings of the ACM conference on Web science*, 42-51.

46. West, S. G., Aiken, L. S., & Krull, J. L. 1996. Experimental personality designs: Analyzing categorical by continuous variable interactions. *Journal of Personality* 64, 1: 1-48.

47. World Press Photo. 2016. World Press Photo of the Year 2015 goes to Warren Richardson. Online article. (18 February 2016). Retrieved May 10, 2016 from http://www.worldpressphoto.org/news/2016-02-18/world-press-photo-year-2015-goes-warren-richardson

48. Zhang, M., and Wang, J. 2009. Psychological distance asymmetry: The spatial dimension vs. other dimensions. *Journal of Consumer Psychology* 19, 3: 497–507.