Article

Environment and Behavior
1–24

DOI: 10.1177/00139165231153160
journals.sagepub.com/home/eab
SAGE

Blue, Rather Than Red Light Can Nudge Employees to Choose Delayed But Larger Wage Payment

Xiaowei Geng[1], Kai Zhang[2], Jiatao Ma[3], Huiming Yang[4], Ziguang Chen[5], and Shu Li[3]

Abstract

Most businesses have been severely affected during the ongoing Coronavirus Disease 2019 (COVID-19) pandemic, as they lack sufficient cash reserves for turnaround in this devastated business environment. This study presents a nudge-based approach for encouraging employees to choose delayed but larger wage payment. Through two laboratory experiments and one field experiment, we found that blue light more likely promotes individuals choosing the farsighted intertemporal option (i.e., delayed but larger payment) than red light. We further investigated why blue light can promote such a farsighted decision and found that the *intradimensional difference comparison*—that is, comparing the difference between the two options in the *time* dimension ($\Delta time_{A,B}$) and the difference in the *payoff* dimension ($\Delta payoff_{A,B}$)—mediates the effect of blue (vs. red) light on intertemporal

[1]Hangzhou Normal University, Hangzhou, China
[2]Ludong University, Yantai, China
[3]Zhejiang University, Hangzhou, China
[4]Zhejiang Painier Technology Inc, Jinhua, China
[5]University of Derby, Derby, UK

Corresponding Author:
Shu Li, Department of Psychology and Behavioral Sciences, Zhejiang University, 866 Yuhangtang Road, Xihu District, Hangzhou, 310058, China.
Email: lishu@psych.ac.cn

choice. The current study demonstrates the effectiveness of light color and provides a solution to nudge people to make farsighted choices.

Keywords
behavior change, blue light, intertemporal choice, nudge, red light

Introduction

To alleviate financial burden in tougher times (e.g., Coronavirus disease [COVID-19] pandemic), delay in paying wages, as one of the surviving strategies apart from reduced salaries, furloughs (i.e., temporary unemployment), changes to indirect compensation packages or any combination of these (Cowling et al., 2020), is usually adopted by businesses, especially small- and medium-sized enterprises. A survey conducted during the COVID-19 pandemic showed that 61% of businesses may run out of cash, including 8.6% that had no retained earnings whatsoever with micro firms at particular risk (Miller, 2020).

To make employees more likely accept delayed wages, employers are usually willing to pay more after a delay, that is, to offer employees a later but larger (LL) payment. Even so, most people discount future rewards and then prefer immediate payment (sooner but smaller, SS) to LL unless a delayed reward is large enough to overcome this discounting (Frederick, 2002; Xu et al., 2020).

Therefore, whether employees can be nudged to choose delayed but larger wage payment is not only a critical problem of whether labor and capital can cooperate and tide over difficulties together but also a scientific problem pursued by researchers focusing on intertemporal choice.

Here, we proposed a method to nudge employees to choose delayed but larger wage payment by making their choice under blue, rather than red light.

Should employees choose a small payment immediately or a larger payment later? This kind of decision is called intertemporal choice, that is, a decision that involves tradeoffs in costs and benefits occurring at different times (Frederick, 2002; Loewenstein & Elster, 1992). In intertemporal choices, people were usually asked to make a series of choices between a smaller-sooner (SS) reward and a larger-later (LL) reward, such as spending money now or saving it to spend later, and taking a job now or getting an education and having a chance at a better job later. Such decisions not only affect one's health, wealth, and happiness but also may—as Adam Smith first recognized—determine the economic prosperity of nations. Strong links have been found between the gross domestic product of a country and the predisposition of its inhabitants to look ahead. In the current question, choosing LL, rather than SS represents a farsighted choice for employees. How, then, can employees be encouraged to make a farsighted choice? We address this issue by examining whether the color of light can encourage a farsighted choice. Confirming the effect of light color on intertemporal choice is important, given its theoretical significance for the implications of relationship between light color and intertemporal choice, as well as the critical policy implications of nudging employees to make a further farsighted decision (i.e., choosing the LL option).

Literature Review

Models of intertemporal choice can be arranged on a continuum, with alternative-based models on one end and attribute-based models on the other. In *alternative-based choice models*, options are independently assigned an overall value, these overall values are compared, and the option with the highest overall value is chosen. In *attribute-based choice models*, options are directly compared along their attributes, and the option favored by these comparisons is chosen (Scholten et al., 2014).

As attribute-based choice models, priority models of intertemporal choice such as the tradeoff model and equate-to-differentiate theory, hold that a decision maker compares the options between the time dimension and the payoff dimension and then makes a choice according to the dominant dimension. According to the tradeoff model of intertemporal choice (Scholten & Read, 2010), people make intertemporal choices by weighing how much more they will receive if they wait longer against how much longer the wait will be, or, conversely, how much less they will receive if they do not wait longer against how much shorter the wait will be. The equate-to-differentiate theory holds that, in intertemporal choice, people tend to compare the difference between the two options in the *payoff* dimension ($\Delta_{payoff\ \mathrm{A,B}}$) and the difference in the *time* dimension ($\Delta_{time\ \mathrm{A,B}}$), and if $\Delta_{payoff\ \mathrm{A,B}} > \Delta_{time\ \mathrm{A,B}}$ ($\Delta_{payoff\ \mathrm{A,B}} < \Delta_{time\ \mathrm{A,B}}$), then people will treat the smaller $\Delta_{time\ \mathrm{A,B}}$ ($\Delta_{payoff\ \mathrm{A,B}}$) as if there is no difference (i.e., will equate them). In other words, the two options are treated as if they have a weak-dominance relationship (Cowling et al., 2020).[1] Following the weak-dominance principle, people are likely to choose the option with a greater value in the payoff dimension or the option with a smaller delay/time in the time dimension (i.e., differentiate) than other available options (Kuang et al., 2022; Li, 2004; Rao & Li, 2011). Based on attribute-based models, time perception is significantly related with intertemporal choice.

Previous studies showed that colors influence people's choices. Kliger and Gilad (2012) examined the effect of color priming in financial decisions and found that red light (vs. green light) emphasized value losses of the underlying asset, that is, elevated the subjective probabilities for investments constructed on the fund's loss-domain and attenuated the subjective probabilities in the gain-domain. Gnambs et al. (2015) found that respondents showed more cautious behavior in a web-based game when the focal stimuli were colored red (vs. blue). Bazley et al. (2018) found that displaying losses in red (vs. black) reduces risk-taking. Velden et al. (2012) examined how the color of chips (red vs. blue or white) used by participants or their competitors affected behavior and found that participants using red chips led their competitors to withdraw. Barone and Winterich (2016) examined the effect of green color (vs. blue) on consumption decisions and found that green color increased consumer preferences for discount promotions versus donation promotions. Gan et al. (2016) examined the effect of color (red, blue, green) on moral judgment, and found that it took longer for people to judge immoral words than moral words when the words were colored green than when they were red or blue.

As a fundamental aspect of human perception, color can also influence time perception. Most research examining this topic has focused on two of the three primary colors—red versus blue (Mehta & Zhu, 2009). Previous evidence suggested that red screens lead to a longer perception of time than blue screens (Gorn et al., 2004; Shibasaki & Masataka, 2014). Red light, which consists predominantly of long wavelengths, is established to induce high levels of arousal (Jacobs & Hustmyer, 1974; Walters et al., 1982; Wilms & Oberfeld, 2018). The relationship between arousal and duration judgments can be described in terms of the pacemaker—accumulator model of time perception (Gibbon, 1977; Gibbon et al., 1984; Treisman, 1963), which proposes a clock device comprising two subcomponents—a pacemaker emitting pulses and an accumulator counting these pulses. The number of pulses accumulated during a defined temporal interval is positively correlated with the perceived length of the interval. High levels of arousal are associated with an increased rate of pulse emission. Therefore, we suggest that the red light elicits the perception of longer duration for people than the blue light.

Thus, compared to individuals under blue light, those under red light would perceive durations to be longer and be more likely to perceive larger differences in the time dimension between the two options of an intertemporal choice ($\Delta_{time\ \mathrm{A,B}}$) than the difference in the payoff dimension ($\Delta_{payoff\ \mathrm{A,B}}$), which would then lead to short-sighted choices. The intradimensional difference comparison will thus mediate the effect of light color (red vs. blue) on intertemporal preference.

We conducted four experiments to test the hypotheses that blue light can promote employees to choose the more farsighted intertemporal choice (i.e., LL option) than red light, and the intradimensional difference comparison may mediate this effect. In all experiments, participants completed the intertemporal choice tasks either under red, blue, or white light provided by a Yeelight LED bulb (model number YLDP02YL), which can emit red light (RGB: 255, 0, 0), blue light (RGB: 0, 0, 255), or white light (RGB: 255, 255, 255), while controlling brightness (perceived intensity of the light; e.g., bright vs. dark) and saturation (difference to an achromatic stimulus, i.e., a neutral gray or white). The laboratory setting was a simulated office environment with a white table (1.2 m × 1.35 m) and a black chair. Participants completed the intertemporal choice tasks on paper. To isolate natural light during experiment, a room without a window was chosen as the experiment setting. Lighting in the laboratory room was standardized at an intensity of 493 lux measured at eye level when participants sat at the table.

Experiment 1: Red/Blue Light and Intertemporal Choice in the Laboratory

Experiment 1 tested the effect of red/blue light on intertemporal choice in the laboratory. Most previous studies on intertemporal choices used a monetary choice task to measure intertemporal choices which may lead to lower ecological validity. To increase the ecological validity, we used three different measures of intertemporal choice: a monetary choice task developed by Kirby et al. (1999) in Experiment 1a and both an ecological version of the intertemporal preference measurement game (Copyright Inheritance Analogue Intertemporal Game, CIAIG) and the intertemporal version of the ultimatum game developed by Shen et al. (2018, 2021) in Experiment 1b. We proposed that individuals may make a further farsighted choice under blue light more than under red light.

Method

According to the calculation of G*Power 3.1 (Faul et al., 2007), under the premise of statistical test force $1-\beta=.80$, bilateral test $\alpha=.05$, and a medium effect $d=0.50$, the number of participants needed to carry out t test of independent samples is 128. Based on this, 133 students from a Chinese university (34 males, age $M=20.86$, $SD=1.04$) participated in Experiment 1a; a total of 136 undergraduates from a Chinese university (26 males, age $M=19.88$, $SD=1.56$) participated in Experiment 1b. Participants were assigned randomly to one of two conditions: blue or red light. In Experiment 1a, 64 participants were in blue light condition and 69 participants were in red light condition. In Experiment 1b, 68 participants were in blue light condition and 68 participants were in red light condition. All participants had no symptoms of color blindness and color weakness and had normal visual acuity or corrected visual acuity. They could not guess the purpose of the experiment. The research was reviewed and approved by the academic ethics committee of the school of education of the university before being conducted. All participants gave their written informed consent prior to the experiment.

In Experiment 1a, a well-validated and widely used monetary choice questionnaire developed by Kirby et al. (1996, 1999) and Kirby (2009) was used, in which participants were presented a fixed set of 27 choices between smaller, sooner rewards (SS) and larger, later rewards (LL). For example, during the first trial, participants were asked "Would you prefer $54 today, or $55 in 117 days?" The delays and amounts were chosen so that hyperbolic and exponential discounting would yield nearly identical orderings of the trials in the degree of impulsiveness required to produce selections of the immediate reward (Kirby & Marakovic, 1996). We took the delay discount rate, *k*, as the index of intertemporal preference, with lower values corresponding to higher levels of foresightedness. Following the literature (Kirby et al., 1999), the *k* values were normalized using natural log transformation because raw *k* values tend to be skewed.

In Experiment 1b, an intertemporal preference measurement game called Copyright Inheritance Analogue Intertemporal Game (http://ccpl.psych.ac.cn:20053/) and an intertemporal version of the ultimatum game were used. (1) *The Copyright Inheritance Analogue Intertemporal Game* (CIAIG) constructs a scenario wherein participants need to wait before they can inherit a writer's royalties (the longer the waiting time, the more the royalties acquired). Participants can independently choose either a younger or an older writer, and their choice can serve as the ecological indicator of their intertemporal preferences. We took the average number of times the participants clicked the "a younger writer" button over 15 rounds of the game as the index of the game. The higher the value, the lower the delay discount rate. (2) *The intertemporal version of the ultimatum game* adds time-interval factors to the original Ultimatum game. The instructions are as follows: *Imagine that you are going to split $1,000 as a reward with someone you don't know. You get $X now and he gets $(1,000−x) a year from now. If you accepted the proposal, you two would get your share at the given time. If you rejected the other's proposal, neither of you gets the money. Here are four proposals, please evaluate the degree to which you are willing to accept each proposal.*

For example, "You get 400 Yuan now, and the other person will get 600 Yuan in a year." "You get 300 Yuan now, and the other person will get 700 Yuan in a year." "You get 200 Yuan now, and the other person will get 800 Yuan in a year." "You get 100 Yuan now, and the other person will get 900 Yuan in a year." As responders, the participants were asked to choose the degree of willingness to accept the proposal on a 6-point Likert scale, where 1 = very reluctant to accept and 6 = very willing to accept. The higher the score, the higher the delay discount rate.

Results and Discussion

Following the literature, we took the delay discount rate, *k* value (Cowling et al., 2020),[2] with lower values corresponding to higher levels of foresightedness, as the index of intertemporal choice, which was normalized using natural log transformation because raw *k* values tend to be skewed (Kirby et al., 1999). Experiment 1a showed that the *k* value was lower under blue light ($M = -5.99$, $SD = 1.02$) than under red light ($M = -4.03$, $SD = 1.16$, $t(131) = -10.33$, $p = .01$, $d = 1.79$, mean difference = 1.96, 95% CI [1.59, 2.34]), suggesting that the participants under blue light were more likely to make farsighted choices. The distribution of *k* (ln) under red and blue light was shown in Figure 1a.

Experiment 1b showed that, for CIAIG, the number of times the participants clicked the "a younger writer" button—with higher values corresponding to lower levels of delay discount—under red light ($M = 5.11$, $SD = 1.61$) was significantly lower than that under blue light ($M = 11.54$, $SD = 2.82$, $t(134) = -16.32$, $p < .001$, $d = 2.80$, mean difference = 6.43, 95% CI [5.65, 7.21]), indicating that the participants under blue light were more likely to prefer farsighted choices. The distribution of number of times clicking the "a younger writer" button under red and blue light was shown in Figure 1b.

For the intertemporal version of the ultimatum game, the willingness to accept the proposal, with lower values corresponding to lower delay discount, was lower under blue light ($M = 12.06$, $SD = 2.71$) than under red light ($M = 15.22$, $SD = 2.70$, $t(134) = -6.81$, $p < .01$, $d = 1.17$, mean difference = 3.16, 95% CI [2.24, 4.08]), indicating that the participants under blue light were more likely to prefer farsighted choices. The distribution of willingness to accept the proposal under red and blue light was shown in Figure 1c.

Therefore, Experiments 1a and 1b both supported the hypothesis that blue light can promote individuals to choose farsighted options (i.e., the delayed but larger payment) compared to red light. Then, how did the blue (vs. red) light influence intertemporal choice? We examined the potential mechanism

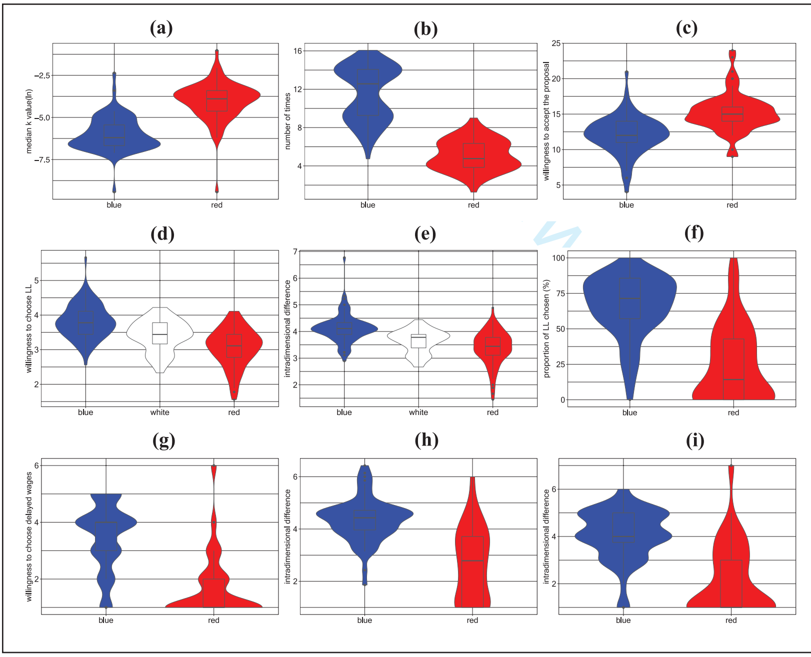

Figure 1. Violin and box plots of the key variables under blue, red, and white (baseline) lights in three experiments. The crossbar of each box represents the median; the bottom and top edges of the box represent the first and third quartiles; the dots represent the extreme outliers. The violin-shaded areas reflect the distribution shape of the data. (a) in Experiment 1a, the median *k* value (ln), with lower values corresponding to more farsighted; (b) in Experiment 1b, the number of times the participants clicked the "a younger writer" button, with higher values corresponding to more farsighted; (c) in Experiment 1b, the willingness to accept the proposal, with lower values corresponding to more farsighted; (d) in Experiment 2, the willingness to choose LL, with higher values corresponding to more farsighted; (e) in Experiment 2, the assessment of intradimensional difference comparison; (f) in Experiment 3, the proportion of LL chosen (%), with higher values corresponding to more farsighted, with higher values corresponding to more farsighted; (g) in Experiment 3, the willingness to choose delayed September wages, with higher values corresponding to more farsighted; (h) in Experiment 3, the assessment of intradimensional difference comparison for the proportion of LL chosen; (i) in Experiment 3, the assessment of intradimensional difference comparison for the willingness to choose delayed September wages.

underlying the effect of blue (vs. red) light on intertemporal choice in the laboratory in experiment 2.

Experiment 2: The Intradimensional Difference Comparison as a Mediator

Experiment 2 investigated the potential mechanism underlying the effect of blue (vs. red) light on intertemporal choice in the laboratory and predicted that the intradimensional difference comparison played the mediating role between the blue/red light and intertemporal choices. Given the lack of control condition in Experiment 1, we had no idea whether people could be more farsighted under blue light than white light. Therefore, three conditions were tested in Experiment 2 (baseline [white light], red light, and blue light).

Method

According to the calculation of G*Power 3.1 (Faul et al., 2007), under the premise of statistical test force $1-\beta=.80$, bilateral test $\alpha=.05$, and a medium effect $f=0.25$, the number of subjects needed to carry out one-way ANOVA was 159. On this basis, a total of 236 college participants (45 males, age $M=18.78$, $SD=1.25$) were assigned randomly to one of three conditions: blue, red, or white light, with 79 participants in red light, 78 participants in blue light, and 79 participants in white light. All participants had no symptoms of color blindness and color weakness and had normal visual acuity or corrected visual acuity. They could not guess the purpose of the experiment. The research was reviewed and approved by the academic ethics committee of the school of education of the university before being conducted. All participants gave their written informed consent prior to the experiment.

The intertemporal choice task was adapted from the monetary choice task developed by Kirby et al. (1999), in which we changed the original alternative-choice paradigm into a 6-point Likert scale to represent the degree of willingness to choose, where 1=very much prefer to choose SS and 6=very much prefer to choose LL. For example, "Would you prefer $54 today (A), or $55 in 117 days (B)?" and 1=very much prefer to choose A, 6=very much prefer to choose B.

The intradimensional difference comparison was measured by a visual analogue scale developed by Jiang et al. (2016), which shows the relative difference in the time and payoff dimensions, as shown in Figure 2 (monetary magnitude and the duration of delay parameters were changed accordingly in other questions). Participants were asked to compare the difference in the time dimension (Δ_{time}) with the difference in the payoff dimension (Δ_{payoff}) on the visual analogue scale. Participants used a left-leaning scale to represent the relative difference when the perceived difference on the time dimension was larger than that on the payoff dimension, whereas they were likely to use

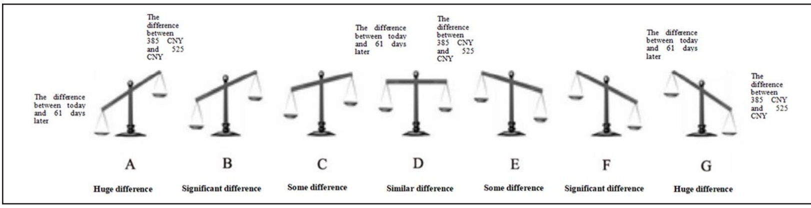

Figure 2. Visual analogue scale.

a right-leaning scale to represent the relative difference when the perceived difference on the payoff dimension was larger than that on the time dimension. If the two were similar, a horizontal scale was used. The degree of leaning to different directions represented relative difference between the two (difference in the payoff and time dimensions). A 7-point scale was used, with a larger scale tilt representing a larger difference between dimensions, while a smaller scale tilt represented a smaller difference. In other words, 1 to 3 suggested that Δ_{time} was greater than Δ_{payoff}, with 1 representing the largest difference between the two, while 5 to 7 suggested that Δ_{payoff} was greater than Δ_{time}, with 7 representing the largest difference between the two.

Results and Discussion

The results of one-way ANOVA analysis showed significant differences among three conditions, $F(2, 235) = 44.65$, $p < .001$, $\eta^2 = .28$. A post hoc test showed that the willingness to choose LL under red light ($M = 3.06$, $SD = 0.55$) was significantly lower than that under white light ($M = 3.41$, $SD = 0.45$), $p < .001$, mean difference = −0.34, 95% CI [−0.50, −0.19] and significantly lower than that under blue light ($M = 3.82$, $SD = 0.50$), $p < .001$, mean difference = −0.76, 95% CI [−0.92, −0.59]; the willingness to choose LL under blue light was significantly higher than that under white light, $p < .001$, mean difference = 0.41, 95% CI [0.25, 0.57]. These results indicate that the participants under blue light were more likely to choose the LL options (i.e., farsighted choices). The distribution of willingness to choose LL under red, blue, and white (baseline) light was shown in Figure 1d.

To identify the mediation role of the intradimensional difference comparison, the bootstrap method was used to estimate the mediating effect (Fang et al., 2012; Wen & Ye, 2014). First, we examined the mediation role of the intradimensional difference comparison in the effect of red/blue light (0 = red, 1 = blue) on intertemporal choices. The experimental condition (red or blue light) had a statistically significant positive effect on participants' willingness

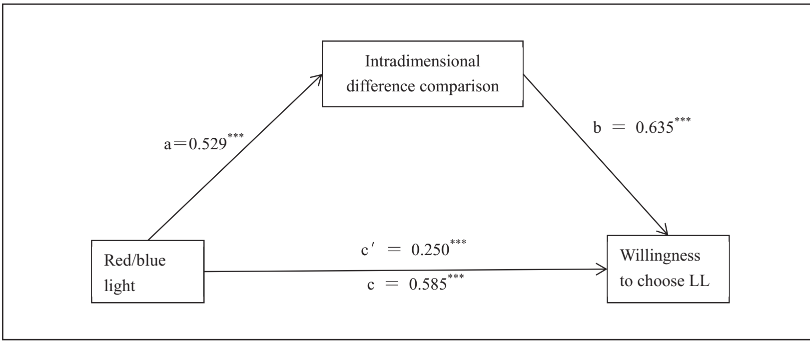

Figure 3. Mediating effect of intradimensional difference comparison on the influence of different color light on intertemporal choice.
Note. Standardized regression coefficients are marked on the path. Red/blue light is a dummy variable, 0 = red, 1 = blue.
***$p < .001$.

to choose LL (c=0.585, t=8.98, $p < .001$) and a statistically significant positive effect on the intradimensional difference comparison (a=0.529, t=7.76, $p < .001$), which means participants were more willing to choose LL and felt Δ_{payoff} was greater than Δ_{time} under blue light than red light. Furthermore, when willingness to choose LL was regressed on the experimental condition and the intradimensional difference comparison, the size of the experimental condition effect was reduced in significance (c'=0.250, t=4.34, $p < .001$) and the intradimensional difference comparison had a statistically significant positive influence on the willingness to choose LL (b=.635, t=11.04, $p < .001$; see Figure 3). Finally, a bootstrapping procedure was used that generated a sample size of 5,000 to assess the mediation effect, the results of a 95% confidence interval indicated that the indirect effect through the intradimensional difference comparison was 0.43, which was significantly different from zero (95% CI [0.2971, 0.5968]) (Preacher & Hayes, 2008).

Second, we examined the mediation role of the intradimensional difference comparison in the effect of red/white light (0=white, 1=red) on intertemporal choices. The experimental condition (red or white) had a statistically significant negative effect on participants' willingness to choose LL (c=−0.325, t=−4.29, $p < .001$) and a statistically significant negative effect on the intradimensional difference comparison (a=−0.229, t=−2.95, p=.004), meaning that participants were more willing to choose LL and felt Δ_{payoff} was greater than Δ_{time} under white than red light. Furthermore, when willingness to choose LL was regressed on the experimental condition and

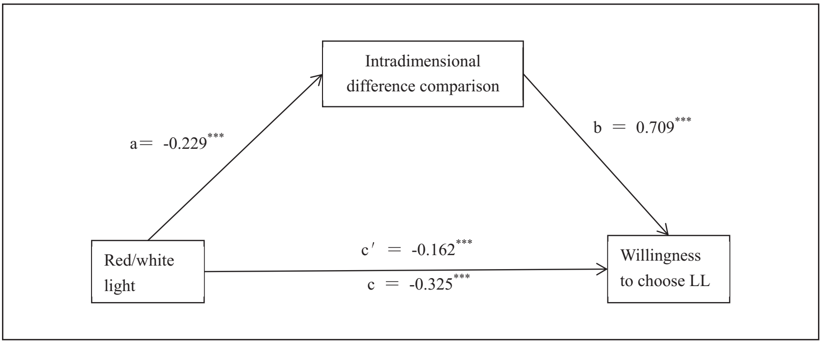

Figure 4. Mediating effect of intradimensional difference comparison on the influence of different color light on intertemporal choice.
Note. Standardized regression coefficients are marked on the path. Red/white light is a dummy variable, 0 = white, 1 = red.
***$p < .001$.

the intradimensional difference comparison, the size of the experimental condition effect was reduced in significance ($c' = -0.162$, $t = -3.04$, $p = .003$) and the intradimensional difference comparison had a statistically significant positive influence on the willingness to choose LL ($b = 0.709$, $t = 13.31$, $p < .001$; see Figure 4). Finally, a bootstrapping procedure was used that generated a sample size of 5,000 to assess the mediation effect, the results of a 95% confidence interval indicated that the indirect effect through the intradimensional difference comparison was −0.17, which was significantly different from zero (95% CI [−0.2836, −0.0603]) (Preacher & Hayes, 2008).

Third, we examined the mediation role of the intradimensional difference comparison in the effect of blue/white light (0 = white, 1 = blue) on intertemporal choices. The experimental condition (blue or white) had a statistically significant positive effect on participants' willingness to choose LL ($c = 0.401$, $t = 5.45$, $p < .001$) and a statistically significant positive effect on the intradimensional difference comparison ($a = 0.443$, $t = 6.15$, $p < .001$), meaning that participants were more willing to choose LL and felt Δ_{payoff} was greater than Δ_{time} under blue light than white light. Furthermore, when willingness to choose LL was regressed on both experimental condition and the intradimensional difference comparison, the size of the experimental condition effect was reduced in significance ($c' = 0.030$, $t = 0.64$, $p = .52$) and the intradimensional difference comparison had a statistically significant positive influence on the willingness to choose LL ($b = 0.838$, $t = 17.80$, $p < .001$; see Figure 5). Finally, a bootstrapping procedure was used that generated a sample size of 5,000 to assess the mediation effect, the results of a 95% confidence interval

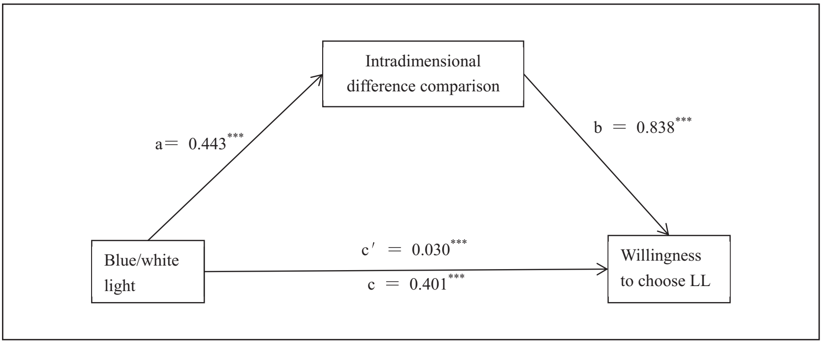

Figure 5. Mediating effect of intradimensional difference comparison on the influence of different color light on intertemporal choice.
Note. Standardized regression coefficients are marked on the path. Blue/white light is a dummy variable, 0 = white, 1 = blue.
***$p < .001$.

indicated that the indirect effect through the intradimensional difference comparison was 0.38, which was significantly different from zero (95% CI [0.2601, 0.5130]) (Preacher & Hayes, 2008). The distribution of intradimensional difference comparison under red, blue, and white (baseline) light was shown in Figure 1e.

The finding of Experiment 1 was well replicated in Experiment 2 that blue light could promote individuals to choose farsighted options (i.e., the delayed but larger payment) compared to red light and further found that the intradimensional difference comparison mediated the effect of blue (vs. red) light on intertemporal choices. In other words, under blue light rather than red light, individuals felt Δ_{payoff} was greater than Δ_{time}, and then preferred farsighted options in intertemporal choices. Given Experiment 1 and Experiment 2 were conducted in the laboratory, Experiment 3 would test the effect of blue (vs. red) light on intertemporal choice in a naturalistic setting.

Experiment 3: The Field Study

Experiment 3 tested the effect of blue (vs. red) light on intertemporal choice in a naturalistic setting.

Method

Partnering with a firm in southeastern China that produces and exports garden tools, we selected 120 employees as participants (72 males, age $M = 33.83$, $SD = 8.04$).

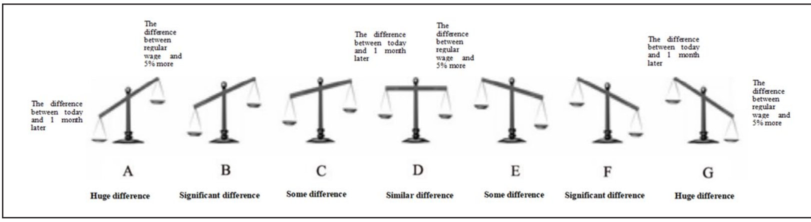

Figure 6. Visual analogue scale regarding the choice of how to receive the September salary.

During the COVID-19 pandemic, the firm faced a huge financial burden and thus sought to alleviate by deciding to adjust the wage system after September 2020. It therefore solicited opinions from its employees via a questionnaire in August 2020. Participants finished the questionnaire under either red or blue light.

The questionnaire included four parts. (1) *Intertemporal choice of wage plans*. Participants were provided seven wage plans. They were asked to choose between one regular wage (SS) and another delayed but larger payment (LL). The proportion of the delayed salary is 1%, 3%, 5%, 10%, 15%, 25%, or 35%, and the delay is 1 month. For example, would you prefer the regular salary this month or receiving 1% more a month later? The final result is the rate of farsighted choices (LL) in the seven choices (Ma et al., 2012). (2) *The visual analogue scale on the intertemporal choices of the seven wage plans*. Participants were also asked to complete the visual analogue scale to compare the difference in the time dimension and the payoff dimension, as shown in Figure 6 (monetary magnitude was changed accordingly in other questions). (3) *The choice of how the wages for the month of September 2020 would be distributed*. Participants were asked to choose how to distribute their own September wages (receive the regular salary this month vs. receive 5% more next month) on a 6-point Likert scale, with 1 representing strong preference for receiving the regular wage in the current month and 6 representing a strong preference for a greater wage the next month. The firm would pay the wage according to the employee's choice. (4) *The visual analogue scale for the choice of how to pay the wages for the month of September*, which shows the relative difference in the time and payoff dimensions, see Figure 6.

To examine the effect of blue (vs. red) light on time perception, we also asked the participants to draw a line representing 10 years (Zauberman et al., 2009) under either the red or blue condition (Cowling et al., 2020).[3] In addition, we asked the participants to report their feelings about red or blue light regarding, such as, comfort, clarity, and so on.

Results and Discussion

For the seven intertemporal choices, participants chose LL less under red light (the rate of LL options is $M=0.25$, $SD=0.27$) than under blue light (the rate of LL options is $M=0.66$, $SD=0.21$, $t(118)=9.22$, $p<.001$, $d=1.70$, mean difference = 0.41, 95% CI [0.32, 0.50]). The distribution of proportion of LL chosen under red and blue light was shown in Figure 1f.

For the choice of how to receive the wage for the month of September, participants were less willing to receive 5% more wage next month under red light ($M=1.67$, $SD=1.14$) than under blue light ($M=3.52$, $SD=1.19$, $t(118)=-8.69$, $p<.001$, $d=1.59$, mean difference = 1.85, 95% CI [1.43, 2.27]). The distribution of willingness to choose delayed payment of wages under red and blue light was shown in extended Figure 1g. In sum, these results suggest that employees were more likely to prefer the delayed but larger payment under blue light than under red light.

To identify the mediation of the intradimensional difference comparison, the bootstrap method was used (Fang et al., 2012; Wen & Ye, 2014). Experimental condition (red or blue light) had a statistically significant positive effect on participants' rate of choosing LL ($c=0.647$, $t=9.22$, $p<.001$) and a statistically significant positive effect on the intradimensional difference comparison ($a=0.591$, $t=7.97$, $p<.001$), which means participants chose more LLs and felt Δ_{payoff} was greater than Δ_{time} under blue light than red light. Furthermore, when rate of choosing LL was regressed on both experimental condition and the intradimensional difference comparison, the size of the experimental condition effect was reduced in significance ($c'=0.240$, $t=4.01$, $p<.001$) and the intradimensional difference comparison had a statistically significant positive influence on the rate of choosing LL ($b=0.688$, $t=11.49$, $p<.001$; see Figure 7). Finally, a bootstrapping procedure was used that generated a sample size of 5,000 to assess the mediation effect, the results of a 95% confidence interval indicated that the indirect effect through the intradimensional difference comparison was 0.26, which was significantly different from zero (95% CI [0.1978, 0.3311]) (Preacher & Hayes, 2008). The distribution of intradimensional difference comparison in the first part under red and blue light was shown in Figure 1h.

For the willingness to choose delayed September wages, the mediation effect of intradimensional difference comparison was also significant. Experimental condition (red or blue light) had a statistically significant positive effect on participants' willingness to choose delayed September wages

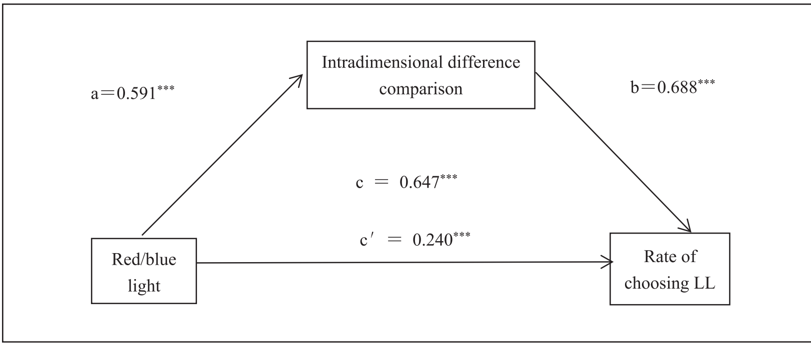

Figure 7. Mediating effect of intradimensional difference comparison on the influence of blue (vs. red) light on intertemporal choice.
Note. Standardized regression coefficients are marked on the path. Red/blue light is a dummy variable, 0 = red, 1 = blue.
***$p < .001$.

($c=0.625$, $t=8.69$, $p < .001$) and a statistically significant positive effect on the intradimensional difference comparison ($a=0.587$, $t=7.87$, $p < .001$), which means participants were more willing to choose delayed September wages and felt Δ_{payoff} was greater than Δ_{time} under blue light than red light. Furthermore, when the willingness to choose delayed September wages was regressed on both experimental condition and the intradimensional difference comparison, the size of the experimental condition effect was reduced in significance ($c'=0.213$, $t=3.49$, $p < .01$) and the intradimensional difference comparison had a statistically significant positive influence on the willingness to choose delayed September wages ($b=0.702$, $t=11.48$, $p < .001$; see Figure 8). Finally, a bootstrapping procedure was used that generated a sample size of 5,000 to assess the mediation effect, the results of a 95% confidence interval indicated that the indirect effect through the intradimensional difference comparison was 1.22, which was significantly different from zero (95% CI [0.8730, 1.6596]) (Preacher & Hayes, 2008). The distribution of intradimensional difference comparison under red and blue light in the second part was shown in Figure 1i.

Perceived time under red light ($M=8.45$ cm, $SD=2.78$) was longer than that under blue light ($M=6.87$ cm, $SD=2.89$), $t(118)=3.06$, $p=.003$, $d=0.56$, mean difference = 1.58, 95% CI [0.56, 2.61]). In addition, there were no significant differences in terms of comfort, relaxation, pleasantness, and clarity under the two different light conditions (ps $> .05$).

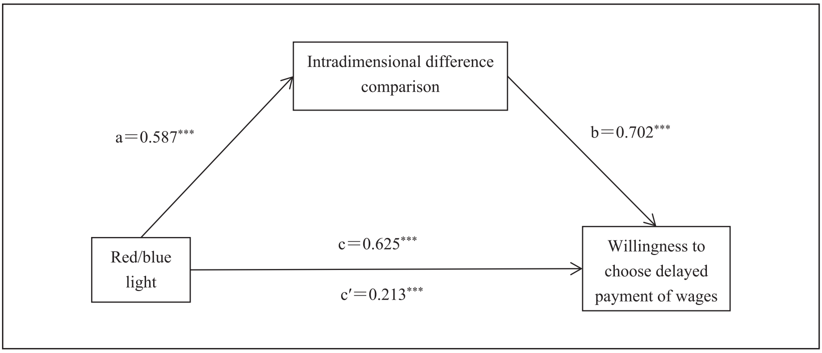

Figure 8. Mediating effect of intradimensional difference comparison on the influence of blue (vs. red) light on intertemporal choice.
Note. Standardized regression coefficients are marked on the path. Red/blue light is a dummy variable, 0 = red, 1 = blue.
***$p < .001$.

Experiment 3 replicated the findings of Experiment 1 and Experiment 2 in a naturalistic setting. Employees were willing to choose the delayed but larger payment under blue light than red light whether for wage plans of the company or their own wage of September. In addition, the intradimensional difference comparison mediated the effect of blue (vs. red) light on employees' intertemporal choices.

General Discussion

Across three experiments, we found consistent and converging support for the nudge effect of blue light on farsighted choices (i.e., delayed but larger payoff). In other words, blue light makes employees be more likely to choose delayed but larger payments than red light. Previous research has found that red stimulation activates the perception of danger (Pravossoudovitch et al., 2014) and that the perception of danger increases the level of excitement, which in turn has a negative impact on decision-making (Knecht & Frazier, 2015). It has also been suggested that processing the word red could lead to poor performance in intelligence tests (Lichtenfeld et al., 2009).

Why was blue light able to help people make a farsighted choice more than red light? One possibility is that light colors change people's time perception and further influence the comparison between the time dimension (Δ_{time}) and the payoff dimension (Δ_{payoff}) in intertemporal choices. If Δ_{time} was larger than Δ_{payoff}, then people would make intertemporal choices based on the time dimension. Otherwise, if Δ_{payoff} was larger than Δ_{time}, then people would make intertemporal choices based on the payoff dimension (Li, 2004; Rao & Li, 2011). The present research found that, compared to red light, blue light led people to perceive time to be shorter, even with identical physical duration. Red is associated with higher levels of arousal (Jacobs & Hustmyer, 1974; Walters et al., 1982), and people with high arousal levels have higher accumulated pulses. According to the pacemaker-accumulator models of time perception (Gibbon, 1977; Gibbon et al., 1984; Treisman 1963), the number of pulses that accumulate during a defined time interval is positively correlated with the perceived length of that time interval (Wearden & Penton-Voak, 1995)—that is, red causes perception of a longer time period. Based on priority models of intertemporal choice, the decision-maker compares the choices between the time dimension (Δ_{time}) and the payoff dimension (Δ_{payoff}) and then makes a choice according to the dominant dimension. Individuals perceived time to be longer under red light, which led to the difference between SS and LL in the time dimension (Δ_{time}) being larger than that in the payoff dimension (Δ_{payoff}). Thus, the time dimension became the dominant dimension under red light, which led to the preference for SS options.

It is also possible that light colors would influence people's emotions and motivations and then influence their decision-making. In many situations, red is associated with danger and perceptions of threat, but blue is associated with relaxation. For example, previous research has found that perceived download time was shorter with blue screen rather than red screen, and this effect was mediated by the greater feelings of relaxation that blue induces (Gorn et al., 2004). Red also increases avoidance motivations in achievement situations (Elliot & Maier, 2014) and leads to decreases in risk-taking (Gnambs et al., 2015). In the present research, we found there was no significant difference in both positive affect and negative affect between red light and blue light. Future research needs to test these possible mechanisms further.

The present research provided recommendations for future agenda. The present research examined the light color (blue vs. red) on individuals' intertemporal choice based on the pacemaker–accumulator models of time perception (Gibbon, 1977; Gibbon et al., 1984; Treisman, 1963). However, we did not directly measure the pulse rate under blue and red light. Future research needs to measure the pulse rate under blue and red light directly to examine the physiological mechanism further.

The present research also has important practical implications. The ability to influence employees to choose larger benefits later (as opposed to smaller benefits soon) is not only viable for many companies but can have a significant impact on economies in general during a recession. Colors are widely present in the financial decision-making arena: at firms' and data providers' websites, television reports, newspaper publications, advertisements, and security market displays, in which colors such as red, blue, and green are prominently employed. Therefore, employers can nudge employees' decision-making by creating different color environments. The present research found that employees could be more farsighted and prefer larger benefits later under blue light, the typical cool color, versus red light, the typical warm color. These findings show employers that an environment with blue light could be beneficial for employees making intertemporal choices.

In sum, the present research first investigated the effect of the color of light on intertemporal choices and found that blue (rather than red) light could nudge individuals to choose a delayed but larger payment. The intradimensional difference comparison—that is, the comparison between Δ_{time} and Δ_{payoff}—mediated the effect of blue light color on intertemporal choices. The present research provided evidence for the priority models of intertemporal choice theoretically. Practically, it can help employers to alleviate financial burden during COVID-19 by nudging employees to choose a delayed but larger payment.

Supplementary Experiment

Procedure. The aim of this supplementary experiment was to examine whether the difference of perceived time length in Experiment 3 remains robust when considering short (in seconds) time perception rather than long (in years) one. One hundred and thirty-three participants sat at the table (1.2 m × 1.35 m), which was located directly under the Yeelight LED bulb (model number YLDP02YL) that emitted red light (RGB: 255, 0, 0) or blue light (RGB: 0, 0, 255) while controlling the brightness (perceived intensity of the light; e.g., bright vs. dark) and saturation (difference to an achromatic stimulus, i.e., a neutral gray or white), resulting in an intensity of 493 lux measured at eye level when participants sat at the table. With a within-subject design, the participants were exposed to both red and blue colored light for 5 s in two different orders: red before blue (red-blue) or blue before red (blue-red), while white light was shown between. The participants were then asked to estimate the duration (in seconds) of the red and blue lights, respectively, and evaluate their emotions on the 5-point PANAS scale (Watson et al., 1988). Considering that in duration estimating task, participants were exposed to both red and blue colored light only for 5 s, which was too short to finish the PANAS scale. In addition, to avoid the influence of order effect on emotion, these participants were asked to evaluate their emotions under blue light or red light with between-subject design next day. In other words, 128 participants (Five participants did not come to complete the PANAS scale) were assigned randomly to red light or blue light. A paired sample *t*-test showed that the perceived time length for the red light (M=4.79, SD=2.25) was significantly longer than for the blue light (M=4.00, SD=1.85, t(132)=4.03, $p<.01$, d=0.38, mean difference=0.79, 95% CI [0.41, 1.19]). An independent sample *t*-test showed that for the positive affect, no significant difference was observed between red light (M=2.77, SD=0.65) and blue light (M=2.88, SD=0.56), t(126)=1.05, p=.29, 95% CI [−0.32, 0.10]. For the negative affect, no significant difference was observed between red light (M=2.05, SD=0.73) and blue light (M=1.98, SD=0.65), t(126)=0.52, p=0.61, 95% CI [−0.18, 0.31]. In other words, in the present study, blue light (vs. red light) did not influence people's positive and negative emotions significantly.

Data Availability

The datasets generated during and analyzed during the current study are available in the Science Data Bank repository https://www.scidb.cn/s/fAnmU3.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research was partially supported by the National Natural Science Foundation of China (71761167001) (71971104), the Major Program of the National Social Science Foundation of China (19ZDA358), the Ministry of Education of Humanities and Social Science project (19YJA190002), and Science and Technology Support Plan for Youth Innovation of Universities in Shandong Province (2019RWF001).

ORCID iDs

Xiaowei Geng https://orcid.org/0000-0001-5265-0679

Shu Li https://orcid.org/0000-0003-4402-1674

Notes

1. Weak dominance states that if Option A is at least as good as Option B in all dimensions, and Option A is definitely better than Option B in at least one dimension, then Option A will dominate over Option B (cf. Lee, 1971; von Winterfeldt & Edwards, 1986).
2. Participants' responses on each trial were converted to discount rates by using Equation $V=1/(A+kD)$, where V is the present value of the delayed reward A at

delay D, and k is a free parameter that determines the discount rate. All delays are measured in days, and the values of k are scaled accordingly.

3. To supplement the *long* time perception (in years) measure of Experiment 3, we investigated the effect of blue (vs. red) light on *short* time perception (in seconds) in a supplementary experiment and found that the perceived time length in the red light (M=4.79, SD=2.25) condition was significantly longer than in the blue light condition (M=4.00, SD=1.85, $t(132)=4.03$, $p<.01$, d=0.38, mean difference=0.79, 95% CI [0.41, 1.19]), which was consistent with the results in Experiment 3.

References

Barone, M. J., & Winterich, K. P. (2016). Does green make you greedy or does it make you go green? The influence of green color primes on consumers' promotion preferences. *Customer Needs and Solutions*, *3*(1), 3–10.

Bazley, W. J., Cronqvist, H., & Mormann, M. M. (2018). *In the red: The effects of color on investment behavior*. Social Science Electronic Publishing.

Cowling, M., & Brown, R. (2020). Did you save some cash for a rainy COVID-19 day? The crisis and SMEs. *International Small Business Journal*, *38*(7), 593–604.

Elliot, A. J., & Maier, M. A. (2014). Color psychology: Effects of perceiving color on psychological functioning in humans. *Annual Review of Psychology*, *65*(1), 95–120.

Fang, J., Qiu, Z., & Zhang, M. (2012). Testing methods of mediating effect and measurement of effect size: Review and prospect. *Psychological Development and Education*, *28*(1), 105–111.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191.

Frederick, S., Loewenstein, G., & O'Donoghue, T. (2002). Time discounting and time preference: A critical review. *Journal of Economic Literature*, *40*(2), 351–401.

Gan, T., Fang, W., & Ge, L. Z. (2016). Colours' impact on morality: Evidence from event-related potentials. *Scientific Reports*, *6*(1), 38373.

Gibbon, J. (1977). Scalar expectancy theory and Weber's law in animal timing. *Psychological Review*, *84*(3), 279–325.

Gibbon, J., Church, R. M., & Meck, W. H. (1984). Scalar timing in memory. *Annals of the New York Academy of Sciences*, *423*(1), 52–77.

Gnambs, T., Appel, M., & Oeberst, A. (2015). Red color and risk-taking behavior in online environments. *PLoS One*, *10*(7), e0134033.

Gorn, G. J., Chattopadhyay, A., Sengupta, J., & Tripathi, S. (2004). Waiting for the web: How screen color affects time perception. *Journal of Marketing Research*, *41*(2), 215–225.

Jacobs, K. W., & Hustmyer, F. E., Jr. (1974). Effects of four psychological primary colors on GSR, heart rate and respiration rate. *Perceptual and Motor Skills*, *38*(3), 763–766.

Jiang, C. M., Liu, H. Z., Cai, X. H., & Li, S. (2016). Process test for intertemporal selection of one-dimensional dominant model. *Acta Psychologica Sinica*, *48*(1), 59–72.

Kirby, K. N. (2009). One-year temporal stability of delay-discount rates. *Psychonomic Bulletin & Review*, *16*(3), 457–462.

Kirby, K. N., & Marakovic, N. N. (1996). Delay-discounting probabilistic rewards: Rates decrease as amounts increase. *Psychonomic Bulletin & Review*, *3*(1), 100–104.

Kirby, K. N., Petry, N. M., & Bickel, N. M. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using controls. *Journal of Experimental Psychology: General*, *128*(1), 78–87.

Kliger, D., & Gilad, D. (2012). Red light, green light: Color priming in financial decisions. *The Journal of Socio-Economics*, *41*, 738–745.

Knecht, W. R., & Frazier, E. (2015). *Pilots' risk perception and risk tolerance using graphical risk-proxy gradients* (Technical report no. DOT/FAA/AM-15/9). Federal Aviation Administration.

Kuang, Y., Huang, Y. N., & Li, S. (2022). A framing effect of intertemporal and spatial choice. *Quarterly Journal of Experimental Psychology*. Advance online publication. https://doi.org/10.1177/17470218221113519.

Lee, W. (1971). *Decision theory and human behavior*. John Wiley & Sons Inc.

Li, S. (2004). A behavioral choice model when computational ability matters. *Applied Intelligence*, *20*(2), 147–163.

Lichtenfeld, S., Maier, M. A., Elliot, A. J., & Pekrun, R. (2009). The semantic red effect: Processing the word red undermines intellectual performance. *Journal of Experimental Social Psychology*, *45*(6), 1273–1276.

Loewenstein, G., & Elster, J. (1992). *Choice over time*. Russell Sage Foundation.

Ma, W. J., Suo, T., Li, Y. D., Luo, L. Z., Feng, T. Y., & Li, H. (2012) The separation of gain - loss framing effects: A study of gain - loss intertemporal choices. *Acta Psychologica Sinica*, *44*(8), 1038–1046.

Mehta, R., & Zhu, R. J. (2009). Blue or red? Exploring the effect of color on cognitive task performances. *Science*, *323*(5918), 1226–1229.

Miller, K. (2020). Sharing the sacrifice, minimizing the pain: Optimal wage reductions. *Economics Letters*, *196*(109503), 1–10.

Pravossoudovitch, K., Cury, F., Young, S. G., & Elliot, A. J. (2014). Is red the colour of danger? Testing an implicit red–danger association. *Ergonomics*, *57*(4), 503–510.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods*, *40*(3), 879–891.

Rao, L. L., & Li, S. (2011). New paradoxes in intertemporal choice. *Judgment & Decision Making*, *6*(2), 122–129.

Scholten, M., & Read, D. (2010). The psychology of intertemporal tradeoffs. *Psychological Review*, *117*(3), 925–944.

Scholten, M., Read, D., & Sanborn, A. (2014). Weighing outcomes by time or against time? Evaluation rules in intertemporal choice. *Cognitive Science*, *38*(3), 399–438.

Shen, S. C., Chen, X., Guo, H. F., & Li, S. (2018). Qualified and unqualified Homo sapiens: The perspective of fiction as behavioral markers. *Science and Technology Review*, *5*, 77–84.

Shen, S. C., Xu, M. X., Zhang, X. J., Yu, L. H., Zheng, R., & Li, S. (2021). Exploring the decision preferences of successful participants of college students' "Innovation and Entrepreneurship Training Program." *Journal of Soochow University*, *9*(30), 98–107.

Shibasaki, M., & Masataka, N. (2014). The color red distorts time perception for men, but not for women. *Scientific Reports*, *4*, 5899.

Treisman, M. (1963). Temporal discrimination and the indifference interval: Implications for a model of the "internal clock". *Psychological Monographs: General and Applied*, *77*(13), 1–31.

Velden, F., Baas, M., Shalvi, S., Preenen, P., & Dreu, C. (2012). In competitive interaction displays of red increase actors' competitive approach and perceivers' withdrawal. *Journal of Experimental Social Psychology*, *48*(5), 1205–1208.

von Winterfeldt, D., & Edwards, W. (1986). *Decision analysis and behavioral research*. Cambridge University Press.

Walters, J., Apter, M. J., & Svebak, M. J. (1982). Color preference, arousal, and the theory of psychological reversals. *Motivation and Emotion*, *6*(3), 193–215.

Watson, D., Watson, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070.

Wen, Z. L., & Ye, B. J. (2014). Mediating effect analysis: Methodology and model development. *Advances in Psychological Science*, *22*(5), 731–745.

Wearden, J. H., & Penton-Voak, I. S. (1995). Feeling the heat: Body temperature and the rate of subjective time, revisited. *The Quarterly Journal of Experimental Psychology*, *48*(2), 129–141.

Wilms, L., & Oberfeld, D. (2018). Color and emotion: Effects of hue, saturation, and brightness. *Psychological Research*, *82*, 896–914.

Xu, P., González-Vallejo, C., & Vincent, B. T. (2020). Waiting in intertemporal choice tasks affects discounting and subjective time perception. *Journal of Experimental Psychology: General*, *149*(12), 2289–2313.

Zauberman, G., Kim, B. K., Malkoc, S. A., & Bettman, J. R. (2009). Discounting time and time discounting: Subjective time perception and intertemporal preferences. *Journal of Marketing Research*, *46*(4), 543–556.

Author Biographies

Xiaowei Geng is a professor at Hangzhou Normal University, China. Her research interests are environmental psychology, behavioral decision making, organizational behavior etc.

Kai Zhang is a doctoral candidate at Ludong University, China. His research interests are intertemporal choice, environmental psychology.

Jiatao Ma is a doctoral candidate at Zhejiang University, China. His research interests are intertemporal choice and organizational management.

Huiming Yang is the CEO of Zhejiang Painier Technology Inc. His research interest is organizational management.

Ziguang Chen is a professor at University of Derby, UK. His research interests are organizational behavior and management decision making.

Shu Li is a professor at Zhejiang University. His research interests are behavioral decision making, organizational behavior etc.