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Greiner, Ben; Stephanides, Marianne

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Ben Greiner
Marianne Stephanides

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WIRTSCHAFTS UNIVERSITÄT WIEN VIENNA UNIVERSITY OF ECONOMICS AND BUSINESS

The economics of colors: A Null result*

Ben Greiner[†] and Marianne Stephanides[‡]

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Abstract

Color research has a long tradition in psychology, consumer behavior, and marketing research. The literature suggests that exposure to colors influences mood and emotions of humans as well as their attitudes towards products. This paper makes two contributions. First, we review the existing literature in science and psychology on the effects of environmental colors (red and blue) on physiological functions, mood, and consumer/economic decision-making, insofar it may be potentially relevant to experimental and behavioral economists. Second, we conduct a laboratory experiment with a typical experimental economics subject pool testing the effects of environmental colors red and blue on decision-making in an incentivized Ultimatum Game experiment. We find no statistically significant effect. However, we also cannot replicate previous results of exposure to colors red and blue on mood as measured by established questionnaire instruments. Our results suggest that experimental economists do not need to worry about the potential confound of colors in economic decision-making.

Keywords: experiment, colors, bargaining

JEL Classification: C72, C90, D91

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[†]Wirtschaftsuniversität Wien, Institute for Markets and Strategy, Welthandelsplatz 1, 1020 Vienna, Austria, e-mail: bgreiner AT wu.ac.at, and University of New South Wales, School of Economics.

[‡]Wirtschaftsuniversität Wien, Institute for Markets and Strategy, Welthandelsplatz 1, 1020 Vienna, Austria, e-mail: marianne.stephanides AT wu.ac.at.

I Introduction

Research on the impact of colors on humans has a long tradition in psychological research. Two main approaches can be distinguished. The first approach studies what colors people like and what that tells us about their personality. The second strand examines how the prime of colors influences people's attitudes, feelings and emotions towards themselves or other people. In clinical applications, the former question culminated in instruments like the color pyramid test (e.g. Schaie, 1963), while the latter resulted in medical treatments like color therapy for people with psychological disorders (e.g. Birren, 1950). An extensive literature in marketing has built on this research, studying how colors moderate people's attitudes towards products and services (see Labrecque et al., 2013; Turley and Milliman, 2000, for reviews).

Behavioral economists have largely ignored colors. The question is, whether rightly so. While there is an abundant literature on physiological reactions to color as well as color effects on mood and emotions, there is little research on the effects of color on actual *behavior* and *decisions*. In this paper, we review existing color research from the angle of behavioral and experimental economics, i.e. with the objective to explore in how far colors may be relevant for economic decision-making. Additionally, we run a laboratory experiment to explore whether the color of an environment can have an effect on economic decision-making in a strategic environment, namely in Ultimatum bargaining. The results of such an endeavor are important in two dimensions. First, if colors affect economic decision making and their effects are not negligible compared to the effect of financial incentives, then economists (as well as any other research concerned with economic or managerial decision-making) should take them into account as a behavioral factor. Second, it is of methodological importance for experimental economists to know whether or not the colors surrounding a decision-environment may affect their results. Treatment effects may be emphasized or mitigated depending on the color of the environment like the background of a computer screen or the light in the laboratory room.

The hypothesized link between colors and decisions based on the existing literature is indirect. Firstly, the colors of an environment may affect biological and brain functions, which result in different emotions and mood of person. Secondly, these states can then translate into different patterns of economic or social decision-making. To support the first leg of this link, there is an abundant literature on how colors affect biological markers, emotions, mood, and attitudes, which we discuss in detail in Section II. With respect to the second leg, there exists evidence on effects of emotions and mood on economic decision-making (Ben-Shakhar et al., 2007; Hopfensitz and Reuben, 2009; Kleef et al., 2004). However, we are not aware of an economic laboratory experiment that directly tests the effect of colors on economic decisions (other than the related studies discussed in Subsection II.H).

The working horse of our experiment is the well-known Ultimatum game (Güth et al., 1982). In this game, a proposer chooses how to split a monetary amount between herself and a responder. The responder can agree or disagree. If the responder agrees, the pie is split as proposed; if the responder disagrees, both receive nothing. This game is well-suited for our purpose for several reasons. First, the game is extremely well-researched, with more than 2000 citations to the original paper to date. Second, the behavior in the game is relatively robust across many different implementations (see also Güth and Kocher, 2014). Offers less than 50 percent are often rejected, and more so the lower the offers are. Typically, the modal offer equals 50 percent of the pie, with a second peak of the offer distribution at zero, and a typical average offer between 30 and 40 percent. Third, based on the existing psychological literature, hypotheses with respect to the effect of the colors red and blue on behavior in the Ultimatum Game are straightforward. The arousal- and sympathy-increasing red color should result in higher offers and more rejections. The cooling color blue should lower offers and rejection thresholds.

We exposed the 192 participants in our Ultimatum game to intense color conditions (more intense than in the typical psychology color experiment). The laboratory was dark, with all lights switched off. The only light in the room came from the screens of the subject computers. These screens had either the background color red (HSB 240°, 100%, 100%; RGB 255, 0, 0), blue (HSB 0°, 100%, 100%; RGB 0, 0, 255), or zTree standard gray RGB(HSB 0°, 0%, 82%; RGB 208, 208, 208). Text was displayed in black font. To further increase exposure, all instructions were given at the screens, and all decisions were made at the screen.

Participants were randomly assigned to either the proposer or the responder role. Proposers made offers (out of a pie of EUR 15), responders stated their minimum acceptance threshold. After the Ultimatum game choices, we elicited subjects' mood using three prominent scales (POMS, PAD, and SAM, see Section III for details). In addition, we let subjects guess the temperature in the (temperature-controlled) room, with payment conditional on the closeness of their guess to the real temperature. Finally, we examined a short demographic questionnaire.

Our main finding is that there seems to be no statistically or economically meaningful effect of intense atmospheric colors on economic decision making in a bargaining task. We cannot detect statistically significant effects of our three color conditions on offers or acceptance thresholds in the Ultimatum game, even though the small observed differences go in the hypothesized directions. However, we also cannot replicate previous findings from psychology that atmospheric colors affect the mood of participants, as measured by the three mood questionnaires. Also temperature guesses were not affected.

There are a few possible reasons why we are not able to replicate previous results from psychology, which we are not able to disentangle. For one, we employ a typical experimental economics subject pool, and our participants are used to be paid for real choices and thus may be less prone to priming through colors. Second, we use a clean between-subject design, while most other studies test the effect of colors within-subjects. Third, we employ different (though more intense) color conditions than the typical psychology experiment. And lastly, there may also be a publication-bias in psychological color research, in that only significant and 'cute' findings find their way into the journals.

All that said, our results imply bad news and good news for behavioral and experimental economists. The bad news are that color research seems not to be a promising field for behavioral economists. The good news are that experimental economists do not have to worry too much about the effect of the color of the laboratory environment on experimental subjects' behavior.

II Existing literature

In this section, we review the empirical literature on the effects of colors on different observable outcome variables. First, we examine the literature of the effect of colors on biological functions such as skin conductance, heart rate, brain activity, etc. (Subsection II.B). Next, we survey the literature on color perceptions, i.e. how colors are interpreted and what meaning they are given by humans (Subsection II.C). This is followed by a review of the experimental literature on how colors affect mood and emotions of humans (Subsection II.D). To establish evidence for a possible link of colors to economic decisions, we take a small detour by showcasing examples from the behavioral economics literature on the link between mood and emotions on the one hand and economic decisions on the other hand (Subsection II.E). Finally we turn to directly examined effects of colors on economic decision-making. Namely, we consider (environmental) color effects on attitudes towards products (Subsection II.F), on working performance (Subsection II.G), and on economic decisions in risky and strategic choice situations (Subsection II.H).

In all sections of this review, we will predominantly focus on results with respect to the effects of the opposing colors red and blue, which are used in our experiment. We include all experimental studies which we could locate (from initial catalogue searches, reference lists, and reference lists of reference lists, etc.) that dealt with the effects of either red or blue color on the above-mentioned outcome variables.

II.A Colors spaces

Different 'color spaces' are used to describe colors. A very popular scheme is the HCL (hue, chroma, luminance) model. *Hue* is the pigment of the color (e.g., red, blue) or the wavelength of colored light, and is expressed as a location on the standard color wheel, in degrees. In common use, hue is identified by the name of the color, such as red, blue, orange, or green. *Chroma* is the saturation of the color, i.e. the amount of pigmentation, or 'purity', of the color. Equivalently, one could interpret it as the amount of gray in proportion to the hue in the color mix. *Chroma* is measured as a percentage, with 0% being a monotone gray (independent of hue) and 100% being the fully saturated color. *Luminance* represents the brightness of a color, its whiteness or blackness. It is also measured as a percentage. A luminance of 0% is always black (no matter what hue or chroma) and a luminance of 100% is always pure white.

An alternative, additive color space is the RGB model, where the light of primary colors red, green, and blue is thought to be combined in order to produce the light of a specific color. The scheme if often used to describe display colors (since traditional monitors were composed of pixels of red, blue, and green light diodes). The relative inputs into the mix are expressed as percentages, such that RGB (0%,100%,100%) represents a turquoise color, for example. RGB (0%,0%,0%) is black and RGB (100%,100%,100%) is white.

II.B Colors and bio-physiological functions

While color has been a subject of the humanities for ages, scientific research into the effects of colors on physiological functions started only in the early 20th century. Pressey (1921) represents an early study, finding some effects of brightness but no effects of color hue (blue, green, red) on a number of bio-physiological functions (pulse and respiration) and performance measurements (cognitive tests etc.). Goldstein (1942, results reported earlier in Goldstein and Rosenthal, 1930) reports his observations of the effects of green and red color on pathological deviations (the preferred position of stretched-out arms of patients with defects of the cerebellum or frontal lobe) and perception of object sizes (for patients with micropsia and macropsia). Green light seemed to correct deviations, while red light seemed to exacerbate them.

In his early review of the color-physiology literature, Kaiser (1984) concluded while there are definitely physiological responses to color ("If there were not, we could not *see* color.", p. 35), with respect to non-visual effects the data on blood pressure, respiration, and heart rate are inconclusive, while the existing effects on galvanic skin response and EEG alpha waves may be cognitively mediated. We come to similar conclusions based on Table 1 where we summarize the results from 16 studies we could find on the effects of blue / red color on bio-physiological functions of humans, with publication dates from 1958 to 2018. The studies examine effects on heart rate, blood pressure, skin conductance, and eye blink rates as measures of arousal, and heart rate variability and EEG alpha waves which represent measures of relaxation.

TABLE 1: Colors and biological functions

	N	Heart rate	Heart rate variability	Blood pressure	Skin conductance	EEG Alpha waves	Eye blink rate
Interpretation		higher $\rightarrow$ more arousal	higher $\rightarrow$ more relaxed	higher $\rightarrow$ more arousal	higher $\rightarrow$ more arousal	higher $\rightarrow$ more relaxed	more $\rightarrow$ more arousal
Gerard (1958)	24	blue$\sim$red		blue$<$red	blue$<$red	blue$>$red	blue$<$red
Erwin et al. (1961)	66					blue$\sim$red	
Wilson (1966)	96				green$<$red		
Jacobs and Hustmyer Jr (1974)	24	blue$\sim$red			blue$<$red		
Caldwell and Jones (1985)	60	blue$\sim$red			blue$\sim$red	blue$\sim$red	blue$\sim$red
Mikellides (1990)	24	blue$\sim$red	blue$\sim$red		blue$\sim$red	blue$\sim$red	
Wolfson and Case (2000)	100	blue$\sim$red					
Hatta et al. (2002)	24	blue$\sim$red					
McManemin (2005)	?	indigo$<$red	mixed results		indigo$<$red		
Schäfer and Kratky (2006)	12		blue$<$red				
Yoto et al. (2007)	11			blue$\sim$red		mixed results	
Küller et al. (2009) Exp1	12	gray$>$colorful				gray$>$colorful	
Küller et al. (2009) Exp2	25	blue$>$red				blue$\gtrsim$red	
Elliot and Aarts (2011)	33		blue,grey$>$red				
Zieliński (2015)	64				blue$\sim$red		
Wilms and Oberfeld (2018)	65	blue$\sim$red			blue$\lesssim$red		

Note: "$\lesssim$" and "$\gtrsim$" refer to directional but statistically non-significant results.

As the table shows, many studies find no effects of color exposure on heart rate, with one study finding that red results in a higher heart rate than blue (McManemin, 2005) and another study finding the opposite (Küller et al., 2009). Thus, there seems to be no consistent evidence that color exposure affects heart rate. Similar inconclusive results seem to exist for heart rate variability, and for blood pressure and eye-blink rate we only have the old significant results from Gerard (1958) or no effects in more recent studies (Caldwell and Jones, 1985; Yoto et al., 2007). More consistent results have been obtained for skin conductance and EEG alpha waves. While there are still Null results reported, if effects have been found, then red increased arousal (as measured by skin conductance) compared to green or blue, and blue increased relaxation (as measured by EEG alpha waves) compared to red.

Other studies examined the effect of colors on motor skills. For example, James and Domingos (1953) find that finger tremor increased after a red light shock, and Goodfellow and Smith (1973) find no differences in psychomotor task performance conducted in boots of different colors. Green et al. (1982) observe that grip strength was significantly higher after viewing a red illuminated wall compared to viewing a blue illuminated wall, while vertical jump power and motor skill precision were not affected, and Elliot and Aarts (2011) report that participants' pinchgrip force was stronger when they were presented with a red compared to a blue participant number on white paper. Smets (1969) report that participants estimate a lower subjective amount of time spent in a red light condition compared to a blue light condition, while Antick and Schandler (1993) find no effect of light wavelength on time perception. These studies, however, seem rather specific and hardly generalizable.

In sum, many studies find no or only inconsistent effects of color on bio-physiological functions. The strongest evidence for color effects comes from studies of skin conductance, where red seems to increase arousal (compared to blue), and EEG alpha waves, where blue seems to increase relaxation (compared to red).

II.C Color perceptions and meanings

Academic research on color *preferences* and their determinants (hue, saturation, or brightness of the color, personal characteristics of the subject) started in the 19th century and reached its peak in the first half of the 20th century. Guilford (1934) and Norman and Scott (1952) provide surveys of these early results.

Lewinski (1938) exposed 30 participants to light of different color and obtained responses on the scales pleasant-unpleasant, stimulating-depressing, and hot-cold. Red was reported to be stimulating and hot while being neutral on the pleasant-unpleasant scale, while blue was judged as cold and pleasant and as neutral on the stimulating-depressing scale. Similarly, Wexner (1954) found that blue was the most positively evaluated color, while red was judged as active, strong, heavy, or intense. Studying written reports and interviews, Gerard (1958) finds that red illumination brings forth a variety of unpleasant associations (e.g. "blood", "injury","fire, heat, danger, pain", and associations of sexual and aggressive nature). Blue light, on the other hand, was evaluated as mostly pleasant.

Other studies tried to decompose effects of different characteristics of colors (hue, saturation, brightness) on a color's perception and meaning. Wright and Rainwater (1962) let a large sample of 3,660 participants rate three-inch square color cards on 48 adjective pairs. They find five main color evaluation factors: "happiness", "forceful-strength", "warmth", "elegance", "calming-strength". The hue of a color was mainly correlated with warmth (red yielding high values), and elegance and calming-strength (larger values with more "blueness"). Also using color pads, Hogg (1969) finds that red is rated high on the warmth scale compared to blue, but wavelength/hue of a color explain only a small part of the overall variation in color evaluation. Using interior design models, Hogg et al. (1979) let participants rate interior space and find that the hue of a wall color is mainly correlated with a room's perceived emotional tone (warmth), while chroma and brightness more strongly affect perceived dynamism and spatial quality (tightness) of the room, respectively. In more recent studies, Yoto et al. (2007) observe blue to be rated lower on perceived warmth than red, and Palmer and Schloss (2010) find that the warm/cold dimension explained 26% of the variance of preferences over colors (the other, less important scales being active/passive and strong/weak).

Adams and Osgood (1973) asked high school students to rate the concepts of colors on adjective scales which describe evaluation, potency and activity. The most positively evaluated color was blue, while the most potent and active color was red. Adams and Osgood (1973) compare their results to 89 other studies, and find many cross-cultural similarities in the affective meanings of colors. In a more recent cross-national study of color preferences, Madden et al. (2000) find that in almost all investigated countries, the colors blue, green, and white are clustered together at the one end of the spectrum of meaning (as "calming," "gentle," and "peaceful") while red usually stands alone at the other end (as "active," "hot," and "vibrant"), with other colors being located between these endpoints. Terwogt and Hoeksma (1995) asked participants to match colors to emotions. Among adults, blue was most often associated with surprise while red was most often related to sadness in the adult group. Among 11-year-olds, however, red was most often associated with happiness.

In sum, there seem to be a broad, cross-cultural consistency in the perception of colors. In general, the warm-cold scale seems to be most strongly associated with the hue of a color. Red often stands for arousal (with associations like "active," "hot," or "vibrant"), while blue can often be found on the other side of the meaning spectrum ("calming," "gentle," or "peaceful"). However, Labrecque et al. (2013) note in their review that color perceptions may also be context-specific.

TABLE 2: COLORS AND MOOD & EMOTIONS

	N	Exp. design	Pleasure / pos. mood	Arousal	Other emotions
Gerard (1958)	24	within			Anxiety: red>blue
Giesen and Hendrick (1974)	96	between	blue∼red		No results for attention, anxiety
Kwallek and Lewis (1990)	222	between			Confusion - bewilderment: green>red, other POMS-scales: red∼green∼white
Kwallek et al. (1988)	36	between			Anxiety: red>blue, Depression: blue>red
Weller and Livingston (1988)	221	between			Color moderates arousal from reading criminal vignettes, blue>pink
Valdez and Mehrabian (1994) Exp2	121	within	blue≳red	blue∼red	Dominance: blue∼red
Kwallek et al. (1997)	90	between			Uneasiness: blue/green<red
Stone (2001)	144	between	blue>red		
Hatta et al. (2002)	24	within		blue∼red	
Gao and Xin (2006)	70	within			No effects of hue on emotions
Yoto et al. (2007)	11	within		blue<red	
Küller et al. (2006)	988	survey	colorful>not c.ful		
Chebat and Morrin (2007)	587	between	no effects	no effects	
Cheng et al. (2008)	150	between	blue>red	blue>red	
Küller et al. (2009) Exp2	25	within			Awake, bored: blue∼red
Küller et al. (2009) Exp3	20	within			Happiness: blue<red
Zieliński (2015)	64	within	blue≳red	blue≲red	
Wilms and Oberfeld (2018)	62	within	high sat: blue>red	blue<red	

Note: "≲" and "≳" refer to directional but statistically non-significant results.

II.D Colors and mood & emotions

Some studies examined the direct effect of colors on the mood and emotions of subjects (as opposed to the subject's association of a color with certain meanings and emotions, discussed in the previous section). A typical study of this kind exposes subjects to a series of color samples (typically color pads) and then measures their current mood/emotions using a validated questionnaire such as POMS, PAD, or SAM (see also our Section III for a detailed description of these questionnaires). Many studies use a within-subject design where the researchers vary the color stimuli and apply the same questionnaire repeatedly to the same participants. Some studies such as Valdez and Mehrabian (1994) even go so far and regress the ratings of different emotional dimensions (e.g. pleasure, arousal, and dominance) on the characteristics of colors such as hue, saturation, and brightness. Jalil et al. (2012) gives an overview over methods used in color-emotions research, and Brengman and Geuens (2004) empirically validated the PAD scale for color research.

In Table 2 we congregate the results of a number of studies on the effects of blue and red color on subject's emotions and mood. This literature can be summarized as follows. If there have been found statistically significant effects of color on positive mood states, then they were mainly in the direction of blue inducing more pleasure than red. Contrarily, in terms of arousal, in those studies where differences have been detected, red induced higher arousal than blue. With respect to other emotion dimensions, red seems to be more associated with anxiety and uneasiness and less with depression, as compared to blue.

II.E Emotions and economic decisions

One link how colors could affect economic decisions may be their ability to influence emotions/mood, which in turn may have an impact on economic decisions. Exemplary evidence for the latter element of the link comes from a number of experimental studies of bargaining games, such as the Ultimatum game studied in our experiment.

Bosman et al. (2001) and Van't Wout et al. (2006) investigate the role of emotions in responders' behavior in the Ultimatum game. They find that lower offers induce stronger negative emotions and higher arousal (measured in Van't Wout et al. (2006) by skin conductance), and that those emotions are positively correlated with the likelihood of rejecting an offer.

Ben-Shakhar et al. (2007) study a version of the Ultimatum game where the proposer decision is framed as (planning to) taking away money from the responder's endowment, and the responder can destruct part or all of their endowment in response. The authors measured emotions after the destruction decision using self-reports and skin conductance. They found both emotion measures correlated to each other and to the amount of destruction. Similarly, Hopfensitz and Reuben (2009) study a sequential social dilemma game with a subsequent punishment stage, and report that first movers who were angry after observing the second mover's choice (based on an emotion questionnaire) punish more than first movers who were not angry. Haselhuhn and Mellers (2005) elicit "pleasure" of proposers over accepted and rejected offers of different sizes, and find that some (selfish) proposers experience pleasure from payoffs and others from fairness. Payoff-pleasure proposers tend to make fair offers in the Ultimatum game but selfish offers in the Dictator game (and thus anticipate displeasure from acceptance and rejection), while fairness-pleasure proposers always behave fairly.

Capra (2004) externally induces a happy or sad mood before one-shot Dictator, Ultimatum, and Trust games. While good mood increases offers in the Dictator game, mood manipulation has only small effects on choices in the Ultimatum game and yields no significant differences in the Trust Game. Both Harlé and Sanfey (2007) and Forgas and Tan (2013) induce mood with short video clips before Ultimatum games and find that responders in sad mood where more likely to reject an offer. Liu et al. (2016) report a similar result from a within-subject study where sad emotional faces induced higher rejection rates. Riepl et al. (2016) induced happiness, anger, fear, and a neutral mood using video clips and find a small increase in the acceptance rate of unfair offers when participants were in the happy mood. Kleef et al. (2004) explore whether emotions expected from the other side strategically change the opponents behavior. Before and during a contract negotiation task, the researchers (deceptively) manipulated the beliefs of participants about the angriness/happiness of their negotiation counterpart. Across three experimental setups, they find that participants react to the emotions of their opponent in predictable ways (concede more to angry opponents than to happy opponents) but only when they have the cognitive capabilities (time) and incentives (low negotiation power) to react on this information.

II.F Colors and attitudes towards products

Colors may highlight product characteristics and influence purchase decisions of consumers. Jacobs et al. (1991) asked 584 Chinese, Japanese, South Korean and U.S. consumers about product characteristic connotations of different colors. They find that these connotations differ across product-categories, but are remarkably consistent across cultures. Red often induces connotations of happiness, love, and adventure, while blue is associated with high quality.

In Table 3 we list the results of various studies that explored how the evaluation of products changed depending on their color, their background's color, or the general (store) environment's color. Across studies, the products tested and manipulations applied are very diverse, and the effects of colors seem highly context- and product-dependent. It appears however, that consistently with the studies of emotional reactions discussed above, red makes a product more exciting. Blue, on the other hand, seems to stipulate connotations of safety.

TABLE 3: Colors and attitudes towards products

	N	Design	Evaluation / Willingness to pay/purchase
Product color			
Anderson (2001)	6 groups	focus groups	Salmon quality: more intense red > less intense red
Gorn et al. (2004)	49	between	Perceived website loading time: red>blue screen backgr.
Alfnes et al. (2006)	115	within	Salmon WTP: more intense red> less intense red
Hanss et al. (2012)	63	within	Colors matched affection-congruently to car types
Labrecque and Milne (2012) Exp3	122	between	Perceived condom ruggedness: red>blue; Perceived condom sophistication: blue>red; WTP: red>blue
Product / screen background			
Mandel and Johnson (2002)	76	between	Cheaper car preferred when green background with $ signs; focus on safety when red background with flames
Lee and Rao (2010)	277	between/within	Web store trustworthiness and willingness to buy: blue>green
Alberts and van der Geest (2011)	220	within	Web site trustworthiness: blue>red, black
Ettis (2017)	465	between	Online store enjoyment and focus: blue>yellow; WTP: blue>yellow
Hsieh et al. (2018) Exp1	120	between	WTP for clothing: blue∼red
Hsieh et al. (2018) Exp2	117	between	Perceived quality: blue>red; WTP for high-price clothing: blue>red, low-price clothing: blue∼red
Print ads / logo			
Gorn et al. (1997)	156	between	Attitudes towards colored brush ad: excitement: blue<red; relaxation: blue∼red; unpleasant feelings: blue∼red
Bottomley and Doyle (2006)	126	within	Red logo better fit for sensory-social products, blue for functional products
Labrecque and Milne (2012) Exp1	279	between	Excitement: blue>red; competence: blue>red
Puccinelli et al. (2013)	597	between	Men: prices in red better deal than black, women: no effect
Sokolik et al. (2014)	1,516,843 ads	between	Ad clicks: blue<red
Puzakova et al. (2016)	130	between	Post-scandal advertising on firm perception: blue>red
Store environment			
Belizzi et al. (1983)	116	between	Pleasure: blue>red; tension: blue<red; activity: blue<red; WTP: blue∼red
Crowley (1993)	100	between	Evaluation: blue>red; activation/arousal: blue∼red
Babin et al. (2003)	161	between	Evaluation: blue>orange; excitement: blue>orange; WTP: blue>orange

Two sub-literatures warrant special mention. First, there is a literature on the relationship between color and food/taste. For food, color may have both aesthetic and important informational value. Anderson (2001) and Alfnes et al. (2006) find that consumers attribute higher quality and a higher willingness to pay for salmon of a more intense red color (see also Table 3). Spence et al. (2010) (24 studies) and Shankar et al. (2010) (>100 studies) both review the empirical literature on how color of food mediates taste and flavor perceptions. They conclude that colors often have cognitive effects (e.g. flavor identification; cherry taste is easier identified if the food is red-colored), but that direct effects of color on taste are heterogenous (e.g. food color appears to affect perception of sweetness but of saltiness, and has no taste perception effects in drinks).

Second, there is a literature on the effect of (atmospheric) store environment on consumer behavior. These studies typically involve architectural models and hypothetical questions, but their setups come closest to our experiment where we change the light in the laboratory room. Turley and Milliman (2000) review the experimental literature on the effects of store atmosphere on customer's mood and purchase behavior, but discuss color only among other characteristics. The studies of store environment color we found and list in Table 3 once again reinforce the findings about color and mood: blue leads to more positive, pleasant evaluations of stores, while red tends to lead to more excitement about the store.

II.G Colors and working performance

A larger number of experimental studies have explored how the color of the environment affects the performance of employees and workers in different tasks. Table 3 provides an overview of the results of a number of papers. Typically, researchers distinguish between creative tasks (inventing options, verbal intelligence, etc.), memory tasks (remembering numbers or letters), logical tasks (anagram and analogy solving), and procedural tasks such as proofreading or typing. In some papers, additionally the difficulty and cognitive demand of tasks were varied. Even though also these studies show a significant amount of heterogeneity in terms of stimuli and outcome measures, some general themes and pattern can be detected. Across studies, blue seems to have the potential to increase performance in creative tasks (compared to red), while results for repetitive tasks (proofreading etc.) seem to be opposite in that people in a red environment perform better than people in a blue environment.

TABLE 4: Colors and working performance

	N	Exp. Design	Color manipulation	Performance variable	Result
Kwallek et al. (1988)	36	between	office walls	typing task	blue∼red
Kwallek and Lewis (1990)	222	between	office walls	proofreading	red<white
Ainsworth et al. (1993)	45	between	office walls	typing task	blue∼red
Etnier and Hardy (1997)	40	within	walls	fine and gross motor tasks	blue∼red
Kwallek et al. (1997)	90	between	office walls	proofreading text	Low sensitivity: blue>red, high sensitivity: blue<red
Stone and English (1998)	112	between	lab partitions	typing task	blue∼red
Wolfson and Case (2000)	96	between	screen background	computer game errors/score	errors: blue>red; score: blue∼red
Stone (2001)	144	between	large panel on desk	reading task	blue,white>red
Hatta et al. (2002) Exp1	24	within	computer screen	symbol coding task	low cog. demand: blue>red
Hatta et al. (2002) Exp2	12	within	computer screen	symbol coding task	high cog. demand: blue<red
Kwallek et al. (2005)	90	between	walls	self-reported performance	blue≳red
Kwallek et al. (2007)	90	between	interior	typing, proofreading zipcodes	color effects depend on subject's environmental sensitivity
Elliot et al. (2007) Exp1	71	between	stimuli frame	anagram solving	green, black>red
Elliot et al. (2007) Exp2	46	between	stimuli frame	analogy solving	green,white>red
Elliot et al. (2007) Exp3	30	between	stimuli frame	analogy solving	green,gray>red
Elliot et al. (2007) Exp4	57	between	stimuli frame	completing sequences	green, gray>red
Elliot et al. (2007) Exp5	48	between	stimuli frame	task choice	easy task: red>green, gray
Kwallek et al. (2007)	90	between	interior	typing task, proofreading	Low sensitivity: blue∼red, high sensitivity: blue-green<red,white
Küller et al. (2009)	20	within	walls	proofreading, creativity task	both tasks: blue∼red
Mehta and Zhu (2009) Exp 2	208	between	computer screen	memory exercise, creativity task	memory: blue∼red; creativity: blue>red
Mehta and Zhu (2009) Exp 3	118	between	computer screen	proofreading, creativity task	proofreading: blue<red; creativity: blue>red
Gnambs et al. (2010) Exp1	131	between	progress bar on screen	vocabulary test	men: green>red; women: green∼red
Gnambs et al. (2010) Exp2	190	between	'forward' button	verbal intelligence test	men: blue>red; women: blue < red
Elliot et al. (2011)	33	between	test paper	IQ test	blue>red
Lichtenfeld et al. (2012) Exp1	69	between	1st screen background	creativity task	green>white
Lichtenfeld et al. (2012) Exp2	35	between	word "Ideas" on instructions	creativity task	green>gray
Lichtenfeld et al. (2012) Exp3	33	between	– same –	creativity task	green>red,gray
Lichtenfeld et al. (2012) Exp4	65	between	– same –	creativity task	green>blue, gray
Steele (2014)	270	between	background color	analogy solving	blue∼red
Shi et al. (2015)	58	between	question text color	Chinese idioms test	blue>red
Xia et al. (2016) Exp 1	125	between	background color	proofreading task	blue<red
Xia et al. (2016) Exp 2	81	between	background color	creativity task	blue≳red, gray

Note: "≲" and "≳" refer to directional but statistically non-significant results.

A special performance context often loaded with myths rather than facts is the world of sports. Hill and Barton (2005) examine data from matches in four men's combat sports (boxing, tae kwon do, GrecoRoman and freestyle wrestling) in the 2004 Olympic Games where red and blue uniforms were randomly assigned, and find that red opponents were more likely to win than blue opponents. The difference between red and blue was stronger for close matches. They argue that the color effect may be facilitated through two channels: competitors wearing red may be more aggressive, and opponents facing a red opponent may react to red as a warning color. Rowe et al. (2005), however, argue that since in the 2004 Olympic judoki matches an advantage of blue over white can be detected, the color red may not be special and the evolutionary explanation based on animal behavior not convincing. Rather, other characteristics of color differences (e.g. visibility, contrast) may be able to explain differences in success.

Other studies have also found higher success frequencies of red sports teams. Attrill et al. (2008) and Allen and Jones (2014) find red-shirt color teams to have bigger long-term success in English football. Ilie et al. (2008) observe red teams to win more often than blue teams in a first-person-shooter online games. However, for the Spanish and German leagues, García-Rubio et al. (2011) and Kocher and Sutter (2008), respectively, cannot detect statistically significant higher success rates of teams with red tricots. Elliot and Maier (2014) and Maier et al. (2015) discuss further studies on the relationship between color and achievement in sports. They hesitate to draw clear-cut conclusions from this literature, noting that achievement environments are complex and their color effects likely context-dependent, and that existing results can only be seen as preliminary.

II.H Colors and economic decisions

There are only a few (experimental) studies that study the effects of colors on economic *decisions*. This is surprising given the breadth of literature of physiological and psychological color effects documented above, and represents the gap which we aim to start filling with this study.

We could locate three studies that examine how colors affect individual risk-taking behavior. In an early study, Stark et al. (1982) expose their 28 participants to blue or red light while making risky choices, and find that subjects invested more money and placed more bets in a red compared to blue environment. In the study by Kliger and Gilad (2012), participants faced a series of investment decisions and were primed with red or green colored backgrounds. Subjects in the red color priming condition put a higher focus on losses relative to gains, compared to subjects in the green condition. In a between-subjects online study, Gnambs et al. (2015) presented 383 participants with classical risky choice tasks presented on a screen with a red or gray header. Effects varied with the presence of a certain option in the choice set. If it was present then subjects were more risk seeking in gray compared to red; if it was not present then subjects exhibited lower risk-seeking in the gray compared to the red condition. In a second, within-subjects study involving the Balloon task with 144 participants, Gnambs et al. (2015) found less balloon pumps (implying less risk-taking) when the balloon was red compared to when it was blue. They conclude that the red color may prime risk or losses to participants. In sum, there is no conclusive evidence yet whether a red color makes people more or less risk-taking.

The only research which we are aware of that studies how color affects decision in a strategic, market context is the paper by Bagchi and Cheema (2013). The paper reports on three studies. In the first study, 16 (12) eBay auctions for an identical product were presented on a red (blue) colored background. Higher bid jumps (increments over current bids) were observed in the red compared to the blue condition. These results were replicated in a hypothetical vignette laboratory experiment. A second study with 89 participants offered subjects a vacation package and asked them to make a best offer, once again varying the offer background color. In this "negotiations" context, subjects in the red condition made lower best offers compared to the blue condition. For a third study the researchers recruited 512 subjects from Amazon MTurk, randomly assigned webpage banner color (red, blue, gray, or white) to subjects, and then confronted them (randomly assigned) to either a hypothetical eBay auction, best offer, or fixed-price listing. Consistent with the other two studies, auction participants in the red condition submitted higher bids than those in the blue condition, while participants in the best-offer treatment showed the opposite color effect, leading to lower offers in red compared to blue. The behavior of participants in the white and gray conditions was similar to those in the blue condition. The authors speculate (and provide some evidence using mediation analysis) that the color effect is mediated by competitive arousal. Red stimulates aggression, and in auctions participants compete with other bidders (yielding higher bids) while in negotiations they compete with the seller (yielding lower offers).

II.I Other reviews of color research

Given the age and size of the color-related academic literature as documented above, there exist a number of reviews of color research. None of these reviews has a focus on colors and economic decisions. In early work, Birren (1950) summarizes results on biological, psychological, and visual aspects of color as well as conclusions for the use of color in a medical context. In an advisory report for NASA in the context of designing a space station, Wise and Wise (1988) review about 200 studies in color research from an environmental designer's perspective, focusing on preferences, physiological responses, temperature, spaciousness, and color assessment. They emphasize that colors have both signal properties handled by limbic mechanisms as well as symbolic associations that rely on high-level cerebral functions.

The reviews of Whitfield and Whiltshire (1990) and Jalil et al. (2012) focus more on the methods used in color research than on results. Both discuss methodological flaws and sample sizes of earlier studies. Elliot (2015) selectively reviews both theoretical and empirical work on color and psychological functioning. He laments that in most of the psychological literature on color, the stimulus color has been imperfectly measured at the device rather than the recipient's eye, and other factors than lightness, chroma, and hue such as viewing distance, angle, amount and type of light, and presence of other colors have been largely ignored.

As cited above, Elliot and Maier (2014) focus on the effects of colors in an achievement and affiliation/attraction context, concluding that color effects are context specific. The review of Maier et al. (2015) zooms in on the effects of the color red in terms of biophysical reactions, association, evaluation, intellectual performance, sports performance, and achievement.

Sorokowski and Wrembel (2014) survey color studies in applied psychology with respect to the effects of colors in marketing, politics, and sports. They conclude that experimental studies often obtained contradictory outcomes, and corresponding ad-hoc theories are frequently inconsistent with modern neuroscience. Aslam (2006) and Labrecque et al. (2013) provide a review on the use of color in marketing and corresponding research results. Both studies highlight the context-dependence of color meanings, with Aslam (2006) pointing to a variation of color meanings across cultures. Already discussed above, Turley and Milliman (2000) review studies on store environment, with color only being one variable among others.

Our review above complements these papers by surveying empirical evidence for color effects on bio-physiological measurements, mood and emotion, product evaluation, and performance, with the goal of exploring possible pathways for effects of colors on real economic decisions. We mainly focused on the prominent colors red and blue.

III Experimental design and procedures

The Ultimatum game (Güth et al., 1982) is one of the most extensively studied games in experimental economics, with various applications (Güth and Kocher, 2014, provide a review). Two players A and B bargain about a distribution of a pie of size P. First, player A proposes how much of the pie P she would like to allocate to player B, while keeping the rest for herself. After being informed about the offer, player B decides whether to accept or reject the proposal. If accepted, the pie will be distributed as Player A proposed; if rejected, both players receive nothing. The only subgame-perfect Nash equilibrium of the game has the responder B accepting any offer larger than zero and the proposer A making the smallest possible offer.[1]

[1] In the discrete case, there can be two subgame-perfect equilibria. If the responder's strategy is to accept a zero offer (that makes him indifferent), then the proposer will offer zero. If the responder rejects a zero offer, the proposer will offer the minimal positive amount.

We implemented the Ultimatum game using the strategy method (Selten, 1967). Namely, we asked player A to state her proposal, and player B to state his minimum acceptance threshold.[2]

We test the impact of three colors on choices in the one-shot Ultimatum game. We chose the colors "blue" (Hue 240 degree, Saturation 100%, Brightness 100%) and "red" (Hue 0 degree, Saturation 100%, Brightness 100%) because psychologists as well as consumer behavior researchers see them as the two extremes on the scale between 'cold-emotionless-calculating' and 'hot-emotional-intuitive' (e.g. Adams and Osgood, 1973; Madden et al., 2000; Wright and Rainwater, 1962, see also our literature review in Section II). We conjecture that if there is a measurable and sizable effect of environmental colors on decision-making, than comparing environments with these two colors would maximize its occurrence. We use the color "gray" as the baseline. In the color research literature, gray is often described as neutral. In addition, the gray color that we implement in our experiment corresponds to the typical background color of the computer screen in the most popular experiment software used in economics, zTree (Fischbacher, 2007).

Our main hypotheses with respect to treatment effects are straightforward. We expect higher offers in condition 'red' (hot-emotional color) than in condition 'gray', and lower offers in condition 'blue' (cold-calming color) than in condition 'gray'. Similarly, for responders we expect higher thresholds in condition 'red' than in condition 'gray', and lower thresholds in condition 'blue' than in condition 'gray'.

After the Ultimatum game, we applied German versions of three different questionnaire measures of mood popular in the psychological and color research literature. First, we administered the Profile of Mood States test (POMS; McNair et al., 1971), which presents subjects with a set of 65 adjectives developed to assess seven dimensions of affective state. For each adjective, subjects describe how good it describes them on a five-point scale (not at all, a little, moderately, quite a bit, extremely). The second test is the Pleasure, Arousal, and Dominance (PAD) test proposed by Mehrabian and Russell (1974). The test consists of 18 adjective pairs that aim to identify three independent dimensions of emotions: pleasure as a measure of happiness and satisfaction, arousal as a measure of stimulation, and dominance as a measure of perceived control and influence. Lastly, we implemented a non-verbal version of the PAD questionnaire, developed by Lang (1985) and Bradley and Lang (1994) (called SAM for' 'Self-Assessment Manikin"). In each of the three emotional dimensions pleasure, arousal, and dominance, the strength of the emotion is represented by a small manikin, and participants select the manikin

[2] Using the strategy method may arguably be 'cooling' the game resulting in lower proposals and lower response thresholds. However, this effect should be present equally in all three color conditions. In their survey of strategy vs. play method experiments Brandts and Charness (2011) observe that applying the strategy method never resulted in a different conclusion with respect to treatment effects compared to the corresponding play method experiment.

which best corresponds to their own feelings. The authors verified the validity of the test by showing its strong correlations with the semantic differential of POMS (Mehrabian and Russell, 1974), and Morris (1995) provides a survey on SAM's use and validity.

Additionally, to verify whether environmental color has an effect on physiological perceptions (in particular whether people perceive the temperature as more cold in a blue environment and more hot in a red environment), we asked participants in the laboratory to guess the room temperature. Guesses were incentivized with a quadratic scoring rule. In particular, participants received EUR 4 minus the squared difference between their guess and the true temperature (with lower payoff bound of zero). The actual room temperature was held (nearly) constant across sessions via the electronic AC controls and was additionally measured with a highly accurate thermometer. For the analysis, guesses where adjusted for the small actual temperature differences across sessions.

Participants were recruited using the online recruitment system ORSEE (Greiner, 2015). Altogether, we recruited 192 subjects into 6 sessions, two sessions for each treatment. The statistical power for a true medium-to-high effect size (f=0.325; Cohen, 1988) is 80.8%. All experiment sessions took place in the evening (in late fall); the windows of the laboratory were further darkened with curtains. At the beginning of the session, the room was illuminated through ceiling lights. Participants received short introductory instructions which did not yet mention the rules of the experiment. Participants were told that the light would be switched off during the experiment, and that the only illumination would come from the computer screens in front of them. Any participant uncomfortable with such a situation was free to leave the experiment at any time. No participant indicated the wish to leave, neither at the beginning nor during the sessions.

Then, the room light was switched off, and computer screens were turned on remotely. The experimental software was programmed with zTree (Fischbacher, 2007). Since the used version of zTree automatically adapted the color scheme of the Windows operating system, we manipulated the Windows OS color scheme according to treatment. Red screens were represented by the RGB color (255,0,0), blue screens used RGB (0,0,255), and gray screens used the default setting of RGB (100,100,100). The computer screens' backgrounds were fully colored with the corresponding treatment color. In all conditions, font color was black, and decision entry fields were framed with thin black lines. No other color appeared on the screen.

The timing of the choices was streamlined across conditions, to keep exposure time to the color prime constant. Experimental instructions on the Ultimatum game appeared on the screen for exactly 5 minutes in all conditions. Then, proposers made their decisions, choosing a price offer between 0 and 15 Euros, in steps of 50 cents. At the same time, responders were asked for the minimum offer they would require in order to accept it (the minimum acceptance threshold).

After Ultimatum game decisions, participants answered the POMS and PAD questionnaires, in that order. Items for each questionnaire appeared on the screen one by one and their order was randomized per subject. The three SAM manikin rows were handed on paper, but choices were made on the screen. Finally, subjects submitted the temperature guess. At the end of the session, we switched on the ceiling lights again. Participants were informed about the results of the Ultimatum experiments, paid out in private and left the laboratory. Participants received a show-up fee of 2.50 Euro plus their earnings from the Ultimatum game and the temperature guess. Sessions lasted about 45 minutes on average.

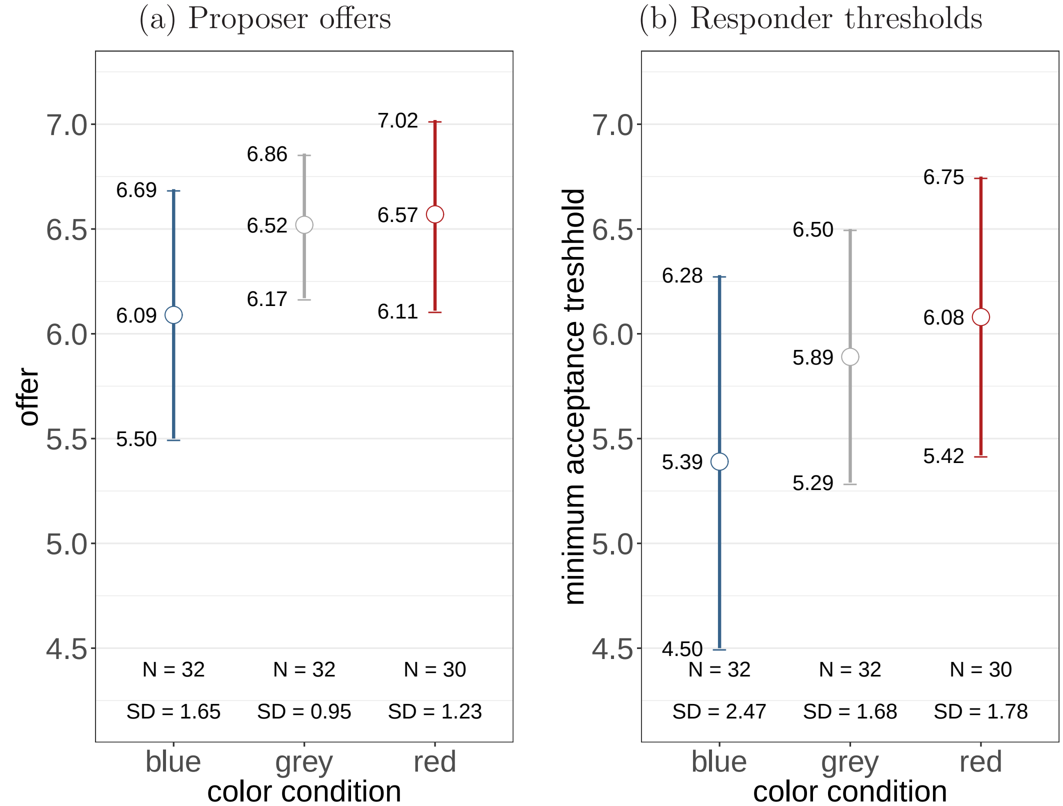
IV Results

Our main hypotheses on the relationship between atmospheric color and decisions were that, relative to the neutral gray color, red increases Ultimatum game offers and minimum acceptance thresholds while blue decreases offers and thresholds. We will first turn our attention to testing these hypotheses. We will then examine the effects of color on mood as measured in the POMS, PAD, and SAM scales, and on temperature guesses. Finally, we examine the correlation between mood and Ultimatum game behavior.[3]

Figure 1 shows average offers and acceptance thresholds as well as their standard deviations and confidence intervals across the three color conditions. Consistent with our hypothesis, we observe higher offers in the gray condition compared to the blue condition, and higher offers in the red condition compared to the gray condition. These differences in averages, however, are rather small, being EUR 0.43 (out of a EUR 15 pie) between blue and gray and EUR 0.05 between gray and red. Similarly, as hypothesized we find lower acceptance thresholds in blue than in gray and in gray than in red, but again differences are small in economic terms (EUR 0.50 between blue and gray and EUR 0.19 between gray and red).

[3]The analysis was conducted with basic functions of R 3.3.2 (R Core Team, 2016). For power analysis and computation of confidence intervals for effect sizes we used the R packages pwr (Champely, 2016) and MBESS (Kelley, 2016), respectively.

FIGURE 1: Means and 95% confidence intervals of offers and acceptance thresholds across the three color conditions



Statistically, these differences are not significant. An Analysis of Variance (ANOVA) on proposer offers yields an $F = 1.25$ with a p-value of $p = 0.293$, and an estimated effect size of $\eta^2 = 0.03$ (confidence interval $[0, 0.11]$). For responder acceptance thresholds, a similar ANOVA yields $F = 0.99$, $p = 0.376$, and $\eta^2 = 0.02$ (confidence interval $[0, 0.09]$).[4] Thus, we cannot detect any evidence that Ultimatum offers and acceptance thresholds vary significantly across the three color conditions.

Table 5 reports results on pairwise comparisons between the conditions. The confidence intervals around pairwise mean differences across color conditions (calculated using Tukey's 'Honest Significant Difference' method) always include zero. Non-parametric Wilcoxon ranksum tests also show no significant differences between color conditions with respect to the distributions of offers and thresholds. We also applied further post-hoc methods to asses the sensitivity of the results, none of which yielded different conclusions.

[4]The aim of our study is to estimate the effect of colors on the general population and not only to the population of non-color-blind people. Therefore, we did not exclude color blind people from participation. However, even if assuming that 10% of participants are color blind (the average prevalence rate in Europe is 4%; Birch, 2012), do not see red in the red condition but a greenish color (like over 95% of color blind people do), and act like the average person in the blue condition, we do not find any significant changes in results (p-values are not significant and potential effect size estimates do not exceed η^2= 0.3).

TABLE 5: Means and confidence intervals of differences between color conditions

	Red – Blue	Gray – Blue	Red – Gray
Offers			
Mean difference [Confidence interval]	0.47 [-0.32, 1.26]	0.42 [-0.36, 1.20]	0.05 [-0.74, 0.84]
Wilcoxon ranksum test	p= 0.467	p= 0.539	p= 0.798
Acceptance thresholds			
Mean difference [Confidence interval]	0.69 [-0.53, 1.91]	0.50 [-0.69, 1.70]	0.19 [-1.03, 1.41]
Wilcoxon ranksum test	p= 0.400	p= 0.864	p= 0.507

Note: P-values are not corrected for multiple testing.

Thus, we find no evidence that would enable us to reject the Null hypotheses of no differences between our three color conditions, and thus find no statistical support for our main hypotheses. In particular, the confidence intervals for effect sizes do not cover medium or large effect sizes (all $\eta^2 < 0.09$). It is therefore unlikely that intense environmental color as implemented in our experiment has an at least medium-sized effect on Ultimatum bargaining behavior.

In an attempt to replicate previous results on effects of colors on mood, we administered the POMS, PAD, and SAM mood questionnaires in our experiment. All questionnaires and factors were coded accordingly to the respective manuals.[5] Table 6 displays mean ratings for all three color conditions as well as for all of them jointly, separately for all subscales of the mood questionnaires. In addition, the table reports results from ANOVA analyses applied to the subscales. We find no significant differences between the color conditions in means of any dimension in any mood questionnaires. None of the confidence intervals (reported in the last column of Table 6) include medium or large effects.[6]

In our analysis reported in Table 7 we turn to the question whether mood, as elicited by the questionnaires, is correlated to the previous behavior in the Ultimatum game. For proposer behavior, we do not find any such relation. For responders, we find that a higher acceptance thresholds are correlated to feelings of less ‘pleasure’ and less ‘dominance’ on the PAD scale (but not on the other scales). Both results, however, disappear when we correct p-values in this analysis for multiple testing.

[5]A coding error in the zTree program led to level 3 and 4 of each POMS item to be recorded as level 3. We reaffirmed the reliability of the POMS subscales (as well as PAD subscales) with a Cronbach alpha coefficient analysis (see Table 9 in the Appendix). Most subscales show sufficient Cronbach alpha coefficients of 0.8. Four scales show values between 0.66 and 0.80. However, since they all rely on only 6-7 items, they can still be seen as acceptable (Cortina, 1993).

[6]Table 11 in the Appendix displays correlations between and within mood measurements. Table 10 ibid. reports means and confidence intervals of differences in pairwise color comparisons, as well as results from Wilcoxon rank sum tests. These analyses yield the same result.

TABLE 6: Average mood ratings for different sub-scales, across color conditions

		Overall	Gray	Blue	Red	ANOVA F p-value	ANOVA η^2 CI for η^2
POMS	Anger-Hostility	16.94	17.47	16.69	16.63	0.57	0.006
		(4.93)	(5.00)	(5.67)	(3.92)	p=0.569	[0, 0.04]
	Confusion- Bewilderment	11.48	11.75	11.30	11.38	0.33	0.004
		(3.34)	(3.07)	(3.64)	(3.33)	p=0.721	[0, 0.03]
	Depression-Dejection	21.11	21.70	21.19	20.40	0.52	0.006
		(7.14)	(7.54)	(7.73)	(6.02)	p=0.596	[0, 0.04]
	Fatigue-Inertia	13.68	14.00	13.31	14.50	0.07	0.001
		(4.33)	(4.42)	(5.08)	(3.96)	p=0.936	[0, 0.10]
	Tension-Anxiety	14.85	15.19	14.50	14.00	0.22	0.002
		(4.21)	(3.33)	(4.89)	(5.07)	p=0.801	[0, 0.02]
	Vigour-Activity	19.70	18.88	20.14	20.12	2.22	0.023
		(3.89)	(3.49)	(4.32)	(3.73)	p=0.111	[0, 0.07]
	Friendliness	20.22	20.19	19.98	20.52	0.38	0.004
		(3.40)	(3.08)	(3.28)	(3.86)	p=0.683	[0, 0.03]
PAD	Pleasure	5.30	4.09	5.67	6.20	0.89	0.009
		(9.21)	(9.83)	(10.09)	(7.37)	p=0.414	[0, 0.05]
	Arousal	2.39	2.09	2.55	2.55	0.08	0.001
		(7.31)	(6.26)	(7.88)	(7.83)	p=0.922	[0,0.01]
	Dominance	1.51	0.20	1.44	2.98	1.43	0.015
		(9.19)	(8.52)	(9.97)	(8.92)	p=0.242	[0, 0.06]
SAM	Pleasure	1.03	1.05	0.80	1.25	1.11	0.012
		(1.70)	(1.70)	(1.87)	(1.48)	p=0.331	[0, 0.05]
	Arousal	-1.22	-1.33	-1.27	-1.07	0.31	0.003
		(1.92)	(1.84)	(2.03)	(1.92)	p=0.735	[0, 0.03]
	Dominance	-0.53	-0.69	-0.41	-0.50	0.52	0.006
		(1.59)	(1.52)	(1.52)	(1.74)	p=0.598	[0, 0.04]
		N=188	N=64	N=64	N=60		

Note: Standard deviations in parentheses. The last column reports effect sizes of ANOVA results and confidence intervals thereof. P-values are not corrected for multiple testing.

TABLE 7: Pearson correlation coefficients between behavior in the Ultimatum game and mood sub-scales

		Proposer offer (N=94)	Responder threshold (N=94)
POMS	Anger-Hostility	0.01	-0.08
	Confusion- Bewilderment	0.06	0.09
	Depression-Dejection	0.06	-0.05
	Fatigue-Inertia	0.04	0.02
	Tension-Anxiety	0.04	0.15
	Vigour-Activity	0.01	0.01
	Friendliness	0.15	0.11
PAD	Pleasure	0.06	-0.22*
	Arousal	-0.06	-0.15
	Dominance	0.02	-0.25*
SAM	Pleasure	-0.11	0.12
	Arousal	-0.01	-0.11
	Dominance	0.01	0.07

Notes: * indicates statistical significance at the 5% level, without alpha level correction for multiple testing. After a Bonferroni (Holm) correction, p=1.000 for all correlations.

Lastly, we examine differences in the laboratory room temperature guesses in the three treatments, and report results in Table 8. On average, participants submitted a temperature of 22.23°C, 22.43°C, and 22.85°C in the blue, gray, and red conditions, respectively (with standard deviations of 2.13, 3.86, and 2.03, respectively). Thus, given these raw guesses, a red room seems to have been perceived as hotter than a gray or blue room. However, in terms of differences to the *actually measured* temperature, the averages are 2.57°C, 2.92°C, and 2.21°C for blue, gray, and red, respectively, and thus do not show such a clear relation. Statistically, we do not detect any significant differences across the three color conditions, neither in raw guesses nor in temperature-corrected values.

TABLE 8: MEANS AND CONFIDENCE INTERVALS OF DIFFERENCES IN TEMPERATURE GUESSES BETWEEN COLOR CONDITIONS

	Red – Blue	Gray – Blue	Red – Gray
Raw temperature guess			
Mean difference [Confidence interval]	0.62 [-0.57, 1.82]	0.21 [-0.97, 1.39]	0.42 [-0.78, 1.61]
Wilcoxon ranksum test	p=0.070	p=0.364	p=0.511
Adjusted for actual room temperature			
Mean difference [Confidence interval]	0.36 [-1.56, 0.83]	-0.34 [-0.84, 1.52]	0.70 [-0.74, 0.84]
Wilcoxon ranksum test	p=0.275	p=0.691	p=0.149

Notes: P-values are not corrected for multiple testing. Confidence intervals are calculated using Tukey HSD.

V Conclusion

We document large and sprawling literatures in medical science, psychology, and marketing that provide evidence for effects of colors on bio-physiological functions, mood and emotions, product evaluation, and task performance. It is thus of interest to explore how colors may affect economic decisions. Using a one-shot Ultimatum game experiment, we test whether different atmospheric colors have an effect on bargaining behavior, namely proposer offers and responder rejection thresholds. We do not find any evidence that this would be the case. While the observed differences between the color conditions go in the hypothesized directions (offers and thresholds being higher in gray than in blue and higher in red than in gray), these differences are very small compared to the pie size and overall variance, and far from being statistically significant.

That is, economic incentives seem to be strong enough to wipe out any effects that colors may have on preferences, mood, or emotions. Thus, color research may not be an avenue that behavioral economists would want to pursue. These results also suggest that findings in consumer research on the effect of colors on attitudes towards products may not necessarily translate into different purchasing decisions, in particular with price differences. On the other hand, experimental economists seem not to need to worry too much about the effect on environmental / atmospheric colors on decision-making in the laboratory.

However, we also cannot replicate previous results on the effect of colors on personal mood (in particular: pleasure and arousal) as measured by standardized questionnaires. This may root in a number of differences between our study and typical psychology studies, such as the use of a different subject pool (accustomed to incentivized experiments), a between-subjects (rather than within-subjects) color treatment design, or an intense atmospheric color prime rather than small-sized color cards. That said, there are also other, more 'psychological' studies that fail to replicate earlier results on the effects of colors on emotions (e.g. Gao and Xin, 2006). Color research in psychology may have suffered from a publication bias.

As a final point, our experiment was naturally designed towards an at least medium-sized effect of colors on decision-making. The very small effects we actually observe could not have reasonably been detected at a statistically significant level with our sample size. If one were convinced that even economically very small effect sizes would be of interest, then that study would need a much larger subject population.

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A Additional tables

TABLE 9: Cronbach's α coefficients for all mood subscales

Mood subscale		Cronbach's α	Number of underlying items
POMS	Anger-Hostility	0.83	12
	Confusion- Bewilderment	0.69	7
	Depression-Dejection	0.91	14
	Fatigue-Inertia	0.85	7
	Tension-Anxiety	0.80	9
	Vigour-Activity	0.73	8
	Friendliness	0.71	7
PAD	Pleasure	0.88	6
	Arousal	0.66	6
	Dominance	0.82	6

TABLE 10: Pairwise comparisons of moods in color conditions

		red–blue Mean diff. [Conf. Int.]	gray–blue Mean diff. [Conf. Int.]	red–gray Mean diff. [Conf. Int.]
POMS	Anger-Hostility	-0.05 [-2.15, 2.04] p=0.282	0.78 [-1.28, 2.84] p=0.077	-0.84 [-2.93, 1.26] p=0.535
	Confusion-Bewilderment	0.09 [-1.34, 1.51] p=0.673	0.45 [-0.95, 1.85] p=0.223	-0.37 [-1.79, 1.06] p=0.415
	Depression-Dejection	-0.79 [-3.83, 2.25] p=0.924	0.52 [-2.48, 3.51] p=0.279	-1.30 [-4.34, 1.74] p=0.275
	Fatigue-Inertia	0.23 [-1.61, 2.08] p=0.592	0.25 [-1.57, 2.07] p=0.517	-0.02 [-1.86, 1.83] p=0.934
	Tension-Anxiety	0.14 [-1.65, 1.94] p=0.598	0.48 [-1.28, 2.25] p=0.167	-0.34 [-2.13, 1.45] p=0.281
	Vigour-Activity	-0.02 [-1.66, 1.62] p=0.691	-1.27 [-2.88, 0.35] p=0.048	1.24 [-0.40, 2.88] p=0.073
	Friendliness	-0.53 [-0.92, 1.98] p=0.363	0.20 [-1.22, 1.63] p=0.430	0.33 [-1.12, 1.78] p=0.871
PAD	Pleasure	0.53 [-3.39, 4.44] p=0.787	-1.58 [-5.43, 2.27] p=0.333	2.11 [-1.81, 6.02] p=0.453
	Arousal	0.00 [-3.12, 3.12] p=0.938	-0.46 [-2.66, 3.58] p=0.572	0.46 [-2.66, 3.57] p=0.597
	Dominance	1.55 [-2.35, 5.44] p=0.438	-1.23 [-5.06, 2.59] p=0.290	2.78 [-1.11, 6.67] p=0.085
SAM	Pleasure	0.45 [-0.27, 1.17] p=0.240	0.25 [-0.46, 0.96] p=0.546	0.20 [-0.52, 0.92] p=0.526
	Arousal	0.20 [-0.62, 1.01] p=0.517	-0.06 [-0.87, 0.74] p=0.965	0.26 [-0.56, 1.08] p=0.486
	Dominance	-0.09 [-0.77, 0.58] p=0.557	-0.28 [-0.95, 0.38] p=0.200	0.19 [-0.49, 0.86] p=0.616

Notes: Confidence intervals (Conf. Int.) are calculated using Tukey HSD. P-values are reported from Wilcoxon ranksum tests, and are not corrected for multiple testing.

TABLE 11: Pearson correlations between different mood scales

		POMS							PAD			SAM	
		A	C	D	F	T	V	F	P	A	D	P	A
POMS	Anger-Hostility												
	Confusion- Bewilderment	0.63*											
	Depression-Dejection	0.65*	0.76*										
	Fatigue-Inertia	0.27*	0.44*	0.39*									
	Tension-Anxiety	0.50*	0.59*	0.57*	0.23								
	Vigour-Activity	-0.19	-0.24	-0.29*	-0.48*	-0.06							
	Friendliness	-0.19	-0.20	-0.22	-0.20	-0.14	0.48*						
PAD	Pleasure	0.57*	0.50*	0.58*	0.46*	0.29*	-0.56*	-0.38*					
	Arousal	-0.14	-0.17	-0.10	0.29*	-0.50*	-0.30*	-0.04	0.12				
	Dominance	0.34*	0.30*	0.32*	0.33*	0.21	-0.35*	-0.31*	0.61*	0.11			
SAM	Pleasure	-0.44*	-0.42*	-0.57*	-0.34*	-0.24	0.37*	0.28*	-0.68*	-0.09	-0.41*		
	Arousal	0.20	0.21	0.29*	0.01	0.34*	0.07	-0.11	0.10	-0.32*	-0.05	-0.12	
	Dominance	0.30*	0.35*	0.39*	0.23	0.27*	-0.24	-0.14	0.42*	0.02	0.44*	-0.40*	0.15

Note: * indicates mood scale correlations that are significant a 5% level, after alpha error correction.