

A Look into Cross-modal Associations between Taste, Color and Music

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ABSTRACT

This paper explores how color and sound can alter taste perception and in particular whether there are any cross-modal associations between these three stimuli. It questions how information from stimuli outside the realms of gastronomy is combined in the brain to influence a person's taste perception. This study tested how colored ambient lighting and piano music can influence people's sweet taste; this is the first experiment to study the associations between all three stimuli. The experiment provided some interesting results; most significantly it was found that the color red and high pitch piano music both have a significant impact upon a person's enjoyment of sweet taste.

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1. INTRODUCTION

The study sits firmly inside the realms of perceptual psychology and explores the theories of cross-modal associations (multisensory interactions) and aims to further understand how color and sound can influence non-synaesthetic people's taste when consuming something sweet. It is known that color and sound can alter a person's mood and feelings, therefore this investigation reviewed similar experiments conducted in controlled laboratory conditions as well as real world applications. The research attempts to show whether the combination of certain sounds/music and colored ambient lighting can have an impact on a person's taste, even though the senses involved in perceiving these stimuli are not linked in any way. Since this study investigated whether and to what extent taste is affected by color and pitch perception, we reviewed (in different sections) the literature on interactions between taste and color as well as between taste and auditory cues. As yet there has not been a study involving these three stimuli combined in non-synaesthetic people.

1.1 COLOR AND TASTE

Color can warn of danger and convey mood hence it is incredibly important in relation to food and cooking. Color is important whilst cooking and is often the first point of sensory contact used to decide on taste opinions [1, 2]. Colors and their meanings are built into a person's culture and are therefore situational and dependent on learnt associations, which can be subject to change [3]. Zampini et al. [4] created an experiment that taste tested different colored flavored and unflavored liquids and found that the participants' flavor identification response was influenced by the color of the liquid. This shows that the visual information presented to them superseded any awareness or learnt associations they had about the particular color and flavor combination.

In 2009, Oberfeld et al. [5] conducted a tasting experiment where participants judged wine in different ambient lighting conditions. Blue was found to be the most pleasant overall, which is in agreement with the average color preferences in western adults [6]. Interestingly, in a red illuminated room, the 260 participants perceived the wine to be 50% sweeter than under the blue, green or white lights. These colors are often used in visual perception experiments and that is why they were chosen for the study presented in this paper. An explanation of these results could be that the differences in color affected the participants' moods (subconsciously), which could have altered their taste as red is commonly associated with the sweet taste [7]. The participants' mood and current state is a

very important aspect in perception studies [8]. A taste testing experiment which involved administering randomly ordered, sucrose solutions of various sweetness (in a blind experiment situation), demonstrated that participants could successfully identify changes in sweetness in clear liquids, yet they could not identify a change when the liquid was red [9]. When only the color had been changed and not the sweetness, they wrongly noticed changes in sweetness when there were none. This is an adaptation of the "Stroop effect" [10] and clearly shows that color can directly alter flavor perception.

1.2 SOUND AND TASTE

Music and taste have been intrinsically linked for centuries; Zarlino, an important musical theorist of the 16th century, described the minor consonances as "sweet" and "soft" [11]. Music and taste descriptive words are often used together subconsciously and can affect a person's decision making. The Fat Duck restaurant in Bray, England serves a dish of seafood with an iPod hidden in a seashell; the iPod plays sounds of the sea through headphones. This sound apparently makes the flavors in the dish stronger and more appealing [12].

Crisinel and Spence [13] created an experiment where 12 different flavors, representing the five basic tastes, were presented to participants while a melody from a number of different instruments was simultaneously played; the audio samples increased in pitch from C2 to C6 (Western scale). They found that the piano was the most pleasant and brass instruments the most unpleasant across all the flavors. The piano instrument was generally preferred in experiments involving the sweet taste and sound. Another experiment involved taste testing different chocolates (milk, marzipan & dark) while listening to music played by varying instruments (piano, strings, woodwinds and brass) in various pitches (C2-C6 western scale) [14]. The piano instrument was most closely linked to high scores of pleasantness but a significant association between chocolate and pitch could not be established, yet a significant relationship between sweetness, pleasantness and the piano instrument was established.

In contrast to other studies, Simner et al. [15] matched the sweet taste to low pitch. However, the high pitch stimulus was described as 'unpleasant' by the participants, whilst the low pitch sound was a pleasant vowel noise. '*Hedonic matching*' is where two separate dimensions of a scale correspond, because both ends of the scale are either pleasant or unpleasant [15].

Therefore the experiment generated correlated results because the sweet taste and low pitch were both perceived as being pleasant, which shows that sweetness is not necessarily linked to high pitch. It has been inferred that the sweet taste has a direct link to the feeling of happiness and pleasantness [14].

2. HYPOTHESIS

It was expected that color will have an impact on taste perception, as it is a strong modifier of taste as shown in previous studies. It was also hypothesised that red would be associated more with the sweet taste.

Hypothesis 1: higher pitches and warmer colors have a positive impact on likings of the sweet taste stimulus.

Hypothesis 2: music and color have a correlation to each other in affecting a person's sweet taste perception.

3. EXPERIMENT DESIGN

The aim of the research was to gain a better understanding of how sound and color together can affect taste and in particular which colors and sounds, and in what combination can affect taste. This involved a deceptive administration experiment [16] as each person was told they will be handed 'different samples' of a sweetened clear liquid yet in reality all the samples were the same. The participants received 24 solutions made of sucrose solidified in water. The participants drank the stimulus 24 times during the experiment under different colored ambient lighting (red, blue, green and white), while listening to three chords, at 2 different pitches. The experiment followed a repeated measures design and so every participant experienced all conditions. All the stimuli were delivered to the participant in a random and controlled manner. Similar to Zampini's et al. [4] experiment, each participant faced a computer screen and wore noise cancelling headphones in a darkened room and remained facing forward throughout the study. Once the oral instruction had been given, further instructions were provided on the screen; the experimenter left the room and the samples were passed through a hatch. This method was applied in order to reduce any external distractions, increase the engagement of the participants as well as remove the human element as much as possible in order to lessen the 'Observer effect' [17]. Each participant was asked the question "How sweet was that taste?" after consuming a sample drink (this was measured on a rating scale from 0 = Not Sweet to 10 = Incredibly Sweet).

3.1 TASTE STIMULUS

The taste stimulus was delivered in clear plastic

shot glasses so the light from the computer screen could illuminate through the liquid and give a greater amount of color influence. Zampini et al. [4] used colored liquid, whereas in this experiment the color of the lighting and not the liquid color itself was tested. After the pilot trials it was decided that 80g of sugar solidified in 1l of water at room temperature (20 ± 2 °C) gave varied results along the 10-point scale and was always deemed 'pleasant', even towards the end of the experiment. The volume of the liquid was set to 15ml as this seemed an adequate amount to properly taste the stimulus. The participants were asked to rinse their mouth with water before starting the test.

3.2 COLOR STIMULUS

This study used similar colors to Oberfeld's et al. [5] experiment as they have been proven to show cross-modal associations. Red, blue and green represent a good proportion of the primary color wheel whereas white was used to simulate neutral lighting. The white light condition served as the control condition and is not expected to create a positive or negative correlation. The exact color attributes are shown in Table 1.

	A	B	L
Blue	28.9	-95.4	71.8
Green	-65.9	68.6	72.3
Red	78.5	54.9	71.2
White	-1.6	-0.1	96

Table 1 - CIELAB color parameters

These parameters were chosen in order to give the most uniform lightness level across all colors. These were created as images which covered the whole computer screen that illuminated the room. The participants in Hasenbeck's et al. [18] experiment were shown pictures of bell peppers at varying luminance levels, and were asked to rate how appealing they were. Yellow and Blue Peppers were enjoyed most at higher luminance levels and were enjoyed significantly less at lower levels. For this reason the luminance levels of all colors in this experiment remained consistent. The luminance level was measured at a distance of 0.5m for each color, which all fell between 150 and 200 LUX, and the initial color temperature of the room was within the desired restaurant color temperature of 4,000K [19].

3.3 SOUND STIMULUS

The variables chosen for this test were note and pitch as they have been used as variables in previous perception experiments. Pitch, in particular, has been proven to have a significant impact on cross-modal associations [20]. It was

decided to use a chord, rather than a melody, song or tone. Using a melody could introduce personal preferences whereas using a single tone may not have been interesting enough or contain enough harmonic content to influence a person's taste perception. A chord was chosen because they are not as complex as harmonies or melodies and are also easier to define and analyse in a quantitative manner.

All of the notes used were in the major scale (chords C, D & E in Major). These chords were chosen as they were in the middle of the chosen octaves, which started at C2 and went up to C4. The low pitch (C2) and high pitch (C4) variants were chosen respectively because they had featured in other studies [13, 14]. Each audio sample was created using a piano emulation synthesizer; the samples had no effects or equalisation added. They had all exactly the same volume (60-70dB), length (8s), velocity and envelope characteristics.

4. RESULTS

The 19 participants who took part in this test were chosen at random and their ages varied between 18-35. None of the subjects reported being color blind or having hearing problems.

The dependent variable in this experiment was the sweet taste perception of the 24 sucrose solutions which was measured on a rating scale from 0-10. The independent variables were the color (4 levels – red, green, blue and white), the pitch (2 levels – high and low) and the note (3 levels – C, D and E). The chosen method of analysis was a repeated measures within-subject factor ANOVA. A three-way ANOVA was performed for all three factors (color, pitch and note) including all possible interactions. The significance value used in the analysis was $P < 0.05$. It was found that none of the factors violated Mauchly's test of sphericity, except for the note against color factor, which had a p value of 0.006; in this exception the Greenhouse-Geisser correction was used, which did not exceed 0.05.

Figure 1 shows the total sweetness rating of the sucrose drink for each color, note and pitch for all participants. This graph exhibits that the sweetness rating of the stimulus increased when the higher pitched audio was used. The low pitch mean total was 5.15 and the high pitch mean total was 6.8. A 27% (+1.675) increase in sweetness level demonstrates that pitch has an effect on taste. Pitch had a significant effect on taste perception ($p < 0.0005$, $F = (1, 18) = 34.086$). A partial Eta squared effect size calculation returned $\eta^2 = 0.545$, which is seen as a large effect size. It was therefore demonstrated that the participants experienced an increase in perceived sweetness whilst listening to the

higher pitched piano sample, as opposed to the low pitched piano sample. The ANOVA found that the notes used in this experiment (C, D and E) did not have a significant effect on taste perception ($F = (2, 36) = 0.249$, $p = 0.781$).

Color was found to have a significant effect on taste perception with a significance value of $p = 0.0005$ ($F = (3, 54) = 7.292$), which also returned a partial Eta squared effect size of $\eta^2 = 0.757$. Figure 2 shows the total mean sweetness level scores for each color (full scale range 0-10). Green and red resulted in the same mean score and so they occupy the high scoring group, whereas white (control condition) was lowest, with blue also occupying the low scoring group. A significant difference can be seen between the high group and the low group, in particular between red/green and blue. On average red and green provided the highest positive cross-modal association with the sweet taste stimulus (the sweet taste perception increased when these colors were used).

However, none of the interactions between the three variables were significant (all $p > 0.05$). This means that no new cross-modal links between multisensory stimuli and taste perception could be established in this experiment.

5. DISCUSSION

The results showed that high pitch piano music generated a clear increase in sweetness ratings which is in agreement with our hypothesis and results from previous studies [13, 21]. The use of taste words as metaphors has been happening for centuries (e.g. sweet melody), it is however unclear as to whether people match sweet tastes to what they perceive as sweet music, based on the correlation between the two ends of the positive or negative aspect of the medium (Hedonic matching) or whether the two are matched together because of the "high-low" terminology used between the two modalities (semantic matching). This could be an area of further research, to try and prove which process humans use when creating subconscious cross-modal associations. The different musical chords used in the experiment did not show to have a significant effect on taste perception. This was not a surprising outcome, as different chords were mainly used to maintain the subjects' engagement. Furthermore, the small change in chord might have been masked by the large changes in pitch and/or the sample size was not big enough to exhibit a trend in the data.

Color showed a statistically significant effect on sweet taste perception, with red and green being linked to higher sweetness scores than blue or white. A probable reason why red and green influenced the level of perceived sweetness is that these colors were generally linked to higher

sweetness than blue or white, as they are more commonly associated with sweets and sugar. The low scoring result of blue and the high scoring result of red and green demonstrate the notion of cross-modal interaction in this experiment. They show that the results were not based on general color preferences but were influenced by the experiment conditions. The process of 'Hedonic matching' could also relate to the color variable as the words used to describe both high sweetness and high pitch, can also be used to describe colors that are higher in tonal range (lighter) and higher in color temperature (warmer), like red is as opposed to blue. This could be another theory that strengthens the synaesthetic bonds between senses since often similar describing words are used or borrowed to describe perceptions outside of that particular sense.

Nevertheless, this experiment has not found new significant associations between colors, piano chords and sweet taste perception.

A possible reason for not reaching any correlations between all three stimuli could be that there is simply no correlation to be made. Perhaps the sample size was not large enough to exhibit a trend in the data however previous experiments have managed to find associations between the senses in smaller sample sizes. Parise and

Spence [22] found synesthetic associations in a sample size as small as 12; this was however between traditional synaesthetic congruencies like pitch and visual size or brightness. These associations are built into our sensory systems from birth and so are formed more quickly and are present in more people [23].

In this study red had the strongest link to the sweet taste, however it was not proven that it has a connection to the sound variable (high pitch) that was also linked to the sweet taste. Therefore even if two variables have shown associations separately with a certain taste group, there is no guarantee that they are compatible together.

6. FUTURE WORK

In the future the test could be repeated by using tones instead of chords as they contain less complex timbres and so a more general understanding of the sound could have been formed, for non-musically trained participants. Another idea of further research could be to involve a lighter shade color condition to go with the higher pitch level condition. This would provide two levels of each stimulus and a semantic correlation possibility. This could help to unify the perception and achieve a unified

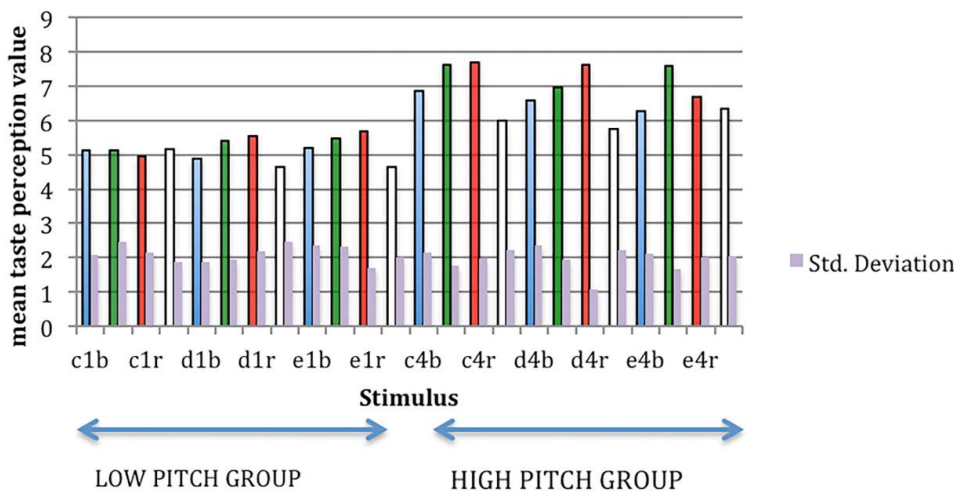


Figure 1 - The graph shows the mean totals for every condition for all participants. The Y-axis is the taste perception ratings scale (full scale 0-10). The X-axis contains every single stimulus condition used in the experiment (e.g. 'c1b' is note C, pitch 1-low and color blue).

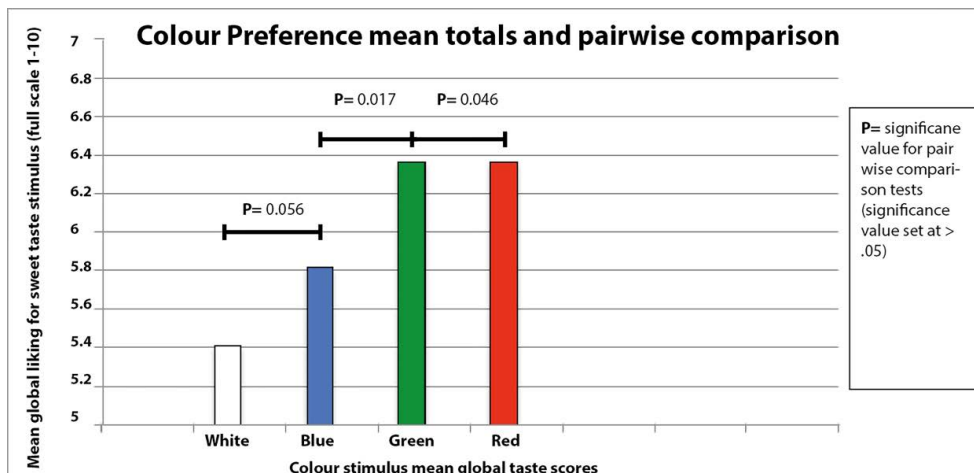


Figure 2 - The Y-axis depicts a scaled version of the taste perception ratings range (full scale 0-10). The X-axis depicts the different colors used in the experiment. The horizontal lines show the pairwise comparison significance values between the low and high scoring colors.

association of color and sound in relation to taste perception. Also the experiment could be modified to include descriptive words of a taste instead of using an actual taste stimulus. This would keep the experiment in the realm of semantics and could provide new cross-modal associations between the words used.

7. CONCLUSIONS

The conclusions that can be drawn from the study are that warmer, brighter colors can increase the sweet taste perception of a sweet taste stimulus. It was also found that the sweet taste was enhanced more under the higher pitched (C4) piano music as opposed to the lower pitched music. It can therefore be concluded that the pitch of an audio sample can affect a person's flavor perception. This shows that information from outside the traditional gastronomical senses can have an impact on a person's taste response. However, the main conclusion is that a relationship between color, sound (pitch and note) and taste was not established in this experiment which could mean that there are no associations between the three stimuli used in this study but it could also entail that the particular stimuli choices may not have been compatible.

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