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Emotions versus semantics: the cross-modal influence of songs on the sweetness of chocolate

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Abstract

Humans perceive their surroundings using five different sensory modalities. Although these senses are independently processed, there can be crosstalk among the different senses. Cross modal correspondences refer to associations made by perceptions from two different sensory modalities elicited by different stimuli. It has been shown that cross modal correspondences can induce cross modal perceptions, whereby independent perceptions affect one another, creating new perceptions of the congruent stimuli. It is known that cross modal perceptions can be caused by semantic or emotional associations generated by the stimuli. However, whether cross modal perceptions occur between the auditory and gustatory senses and their relative dependence on semantic and emotional associations is not known. To this end, the change in the perception of sweetness was tested in response to two different pieces of music that were connected to the sweetness of chocolate by meaning (semantic) or by pleasure (emotion). After listening to the pleasurable song, the same piece of chocolate induced a stronger sense of sweetness compared to before listening to the song or after listening to the semantically "sweet" song. The results suggest that emotions, specifically pleasurable experiences, may be a more dominant cause of cross modal perceptions between the gustatory and auditory senses. Future research in the field can utilize this information to find the mechanism(s) of these cross-modal perceptions. These findings may have implications for improving marketing strategies for in-store food sampling, whereby a more hedonically stimulating song could be used to increase the customer's perception of sweetness in the products sampled.

Keywords

Cross modal perception, Perception, Taste, Semantic, Multisensory, Emotions, Hedonic, Auditory, Gustatory, Sweetness

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Introduction

The five basic senses that humans use to sense the environment are sight, hearing, smell, touch, and taste. The sensory systems allow sensory modalities/senses to be perceived, which is a feature of a stimulus or the experience/perception of the stimulus. These sensory modalities are perceived by different organs of the body and help us interact with our surroundings. Although each sense is processed individually, the different senses can interact with each other. When features of different stimuli perceived from different senses become associated with one another, the phenomenon is referred to as cross modal correspondence. Recently, cross modal correspondences were shown to elicit a phenomenon called cross modal perception. Unlike cross modal correspondences, cross modal perceptions are not mere associations but occur when the different perceptions from two different stimuli affect one another, causing changes in the individual perceptions of those stimuli. Thus, cross modal correspondences can be incorporated into active perceptions, creating new perceptions of a certain stimuli. For example, if an individual formed correspondences between the ‘softness’ of a song (Stimulus A) and the softness of a fabric (Stimulus B), the congruency between the softness feature of those stimuli could induce a cross modal perception pertaining to the softness of the music or the cloth. In other words, the cloth would feel softer while listening to the song, or the song could be perceived as softer while feeling the fabric.

However, there is a lack of understanding on how cross modal perceptions are induced, preventing the field of study from progressing further. Thus, there is a need to provide further data that will aid in understanding how cross modal perception works. Such elucidation would have useful applications in neuroanatomy and neurophysiology. Obtaining information on the phenomenon would potentially provide insight into how the sensory lobes of the brain are communicatively and structurally connected. New data could also improve marketing strategies for businesses, since a knowledge of stimuli that elevate sensory experiences can be utilized in consumer environments to elicit and/or strengthen buying initiatives in customers. This study aimed to close the gap in such knowledge by performing an analysis between the proposed causations of cross modal perception, specifically pertaining to cross modal perceptions between the auditory and gustatory senses.

Literature review

There are multiple ways in which cross-modal correspondence can be initiated. Semantic, statistical, structural, and emotional processes constitute some of them (1). Semantically mediated correspondences are elicited when features of a stimulus share the same set of lexical or metaphorical meaning (2). For example, there can be congruency between a song described as soft and subtle, and a soft blanket, as they both share a set of terms by which they can be described. Structurally mediated correspondences occur when the stimuli are congruent based on common physiological interpretation, such as correspondence surrounding the intensity of stimuli. Brightness and loudness can be congruent due to their sharing of their perceived intensity to the individual. Correspondences can also be caused by statistical means when the congruency occurs based upon the probability that the stimuli are learned together. For example, the size of an object can correspond to a certain pitch, i.e., a smaller object is correlated with a higher pitch due to learned and conditioned responses and observations.

Emotional cross modal correspondence occurs when the stimuli are associated based on the emotions/mood that they induce. For instance, dark and dull colors like gray, and a somber song can correspond as they both induce a melancholy feeling.

Although the general phenomenon of cross-modal correspondence has been recognized by researchers (1, 3-5), a recent discovery sparked a new discussion within the field. Experiments suggested that these mere correspondences could be recognized through their ability to induce changes in perception of the feature that the two stimuli were congruent upon. From the mounting amount of evidence and information surrounding cross modal correspondence, researchers (1, 6, 7) were able to identify cross modal perception, a phenomenon derived from cross modal correspondence. Cross modal perceptions are changes in the perception of the feature that two stimuli, perceived from different senses, were associated upon (cross modally). As previously mentioned, an example of cross modal perception would be the change in the softness of a piece of fabric in the presence of music when correspondences could be formed between the softness of a song and the softness of a fabric. An important aspect of cross modal perceptions is that the two stimuli need to be present at the same time. It is as yet unknown as to what part of the active perception of stimuli is chosen to be affected. Spence et al. reported on the association of cross modal perception and cross modal correspondences, finding that some form of correspondence between two stimuli was essential for cross modal perceptions, further defining the role of cross modal correspondences in the newly discovered phenomenon (1). The observed changes of perceptions in the presence of cross modal correspondence suggested that the perception is dependent on the phenomenon. Therefore, it was concluded that cross modal perception must be observed in the presence of cross modal correspondence.

The results of past studies support the role of modal correspondence in perceptions, further strengthening the connection between the two phenomena. Those studies suggested that the phenomenon of cross-modal perceptions was largely dependent on cross-modal correspondences (7-9). Although it has been determined that cross-modal correspondences cause cross modal perceptions, the underlying mechanism is unknown. However, since the causation of cross-modal correspondences are known, the causes of cross-modal perceptions can potentially be elucidated. Due to the evident dependence of cross-modal perception on cross-modal correspondences, researchers have found that the causes of cross-modal correspondences are also responsible for the phenomenon of the manipulation of active perception (10, 11). However, not all causations (emotional, statistical, semantical, structural) of cross modal correspondences apply to cross modal perceptions. From the current existing literature, cross modal perceptions seem to arise from only the emotional, structural, and semantical causations (3, 4, 9, 12).

From the multitude of cross modal pairings that can be made between the 5 sensory modalities, the congruencies and perceptions between the gustatory and auditory modality have been the most recently researched area of cross modal perception and cross modal congruency. The modes of causation of active perception with these two modalities have also been identified, ranging from the emotional to semantical causation (5, 12, 13). Studies surrounding cross modal perceptions between the auditory and gustatory modalities determined that a lyric-less song induces a change in the flavor-profile of the tasted food. Although the studies conducted surrounding this type of correspondence found similar results, researchers concluded different attributes of music as being responsible for inducing the corresponding responses in taste perception. Reinoso-Carvalho et al. highlighted the prominent role of emotionally mediated congruencies, finding strong evidence of the effect of positive (vs. negative) valanced soundtracks on the perceived sweetness of chocolate (5). Others found that cross modal perceptions were induced by semantics, as participants reported that finding meaning in the lyrics affected the flavor profile of the tasted food (6, 14, 15). However, Bravo-Moncayo et al., have claimed that the results could not be attributed to cross modal interactions but due to masking effects induced by the music, or due to the increased cognitive load of the music (16). Despite each study finding the same results, they drew different conclusions on how the phenomena occurred. Such ambiguity of the causation must be probed further to clearly define the mechanism of the phenomenon (specifically perceptions between the auditory and gustatory modes).

The contemplation on the mode of cross modal perceptions in the auditory and gustatory modalities is divided between two causations, one being semantically mediated and the other being emotionally mediated. The semantic causation purports that the perceptions induced by music influence taste perception in a meaning/identity manner. For example, if the participants find a piece of music to be positively valanced, they may interpret it as happiness, and then correlate happiness to sweetness, since in the Anglo-Saxon culture, the two modes are frequently correlated with each other (17). The semantic causation will then, in turn, change the perception of the food, perceiving it to taste sweeter when listening to the music. This supports the notion that innate feelings directly manifest in the perception of the taste of the food. For example, liking the music will make the flavor of the food closer to the preferred taste. The emotionally mediated congruencies have no relation with the meaning of the emotion, rather, the feeling of the emotion itself is the factor that allows the two stimuli to be congruent. In contrast, semantic causation requires the recognition of the meanings laced with emotions and aims to metaphorically connect that meaning when inducing cross modal perceptions. Despite the differences between semantic and emotional correspondences, researchers find similar results on the active perceptions that are induced through either the semantic pathway or emotionally mediated pathway. Therefore, there is a gap in the knowledge of whether there is dominance of the semantic pathway or the emotionally mediated pathway during cross modal perception of taste and music. In addition, there is a lack of information surrounding the mode of specific causations (emotional and semantical) in cross modal perceptions.

To uncover more information on the basis of this phenomenon and to test whether dominance exists in the causation (semantic vs. hedonic), this study investigated how the sweetness of chocolate was interpreted while listening to two different types of music, to obtain greater insight into the dominance of the semantic/metaphorical meaning of music or the innate emotions induced by the music on the perception of taste. Data from past studies on cross modal perception through the gustatory and auditory modalities would seem to suggest that semantic and emotional causations would display an equal magnitude of dominance on cross modal perceptions and changes in the perceived sweetness of the tasted food.

Materials and Methods

The debated two modes of causation (emotional and semantic) were represented by two different songs, a hedonic song, and a semantically mediated song. The hedonic song was a personally chosen song by each participant that induced pleasurable feelings within themselves. Jialing Deng, and Harlin Sun's "sweet song" from Deng's Master of Arts Thesis project was found to enhance sweetness through the sharing of a semantic space (18). Thus, Deng and Sun's "sweet song" was chosen to induce semantical causation in the participants. The participants' perception of the sweetness of a piece of chocolate (56% Cacao Baker's Premium Semi-Sweet Chocolate Baking Bar, Dover, Delaware) in response to the hedonically mediated music and semantically mediated "sweet" music was measured. Using this information, the relative strengths of emotional and semantic causes on cross-modal perception were determined.

To determine the dominance of either semantic or hedonic causation in cross modal perceptions of sweetness, the survey and the taste test were completed by 52 high school students (11, 15, 19). A quantitative one-shot research design was conducted on these high schoolers (ages 14-18 years old) in a suburban high school located in Pennsylvania. It was determined that examining teens instead of adults addressed a population gap in study. Within the age range, the high school students were chosen in a random manner and randomized into 2 separate groups, whereby Group 1 tasted chocolate while listening to a hedonic song followed by a semantically sweet song and Group 2 that tasted the chocolate with songs in the reverse order. Thus, each participant tasted 3 identical pieces of semi-sweet chocolate, first without listening to music (internal control) and then under two experimental conditions where they listened to a hedonic song and a semantically sweet song. It was determined that semi-sweet chocolate would be preferred over other forms of chocolate, as the sweet and bitter nature of the chocolate allows probing of changes in the sweetness level of the chocolate. To establish a baseline for the sweetness of the chocolate, the participant was first asked to taste the chocolate without listening to music and told to rate that sweetness as a score of 3 (sweetness range of 1-5). Using this "no music" control condition and a 5-point scale, the changes in the sweetness of chocolate under the experimental conditions were analyzed in a standardized manner for each participant. The 5-point scale was used as the sweetness level perceived for each participant, where lower numbers indicated bitterness and higher numbers indicated heightened sweetness.

To find the changes in sweetness level, the participants were asked how the sweetness of the chocolate changed when consumed under the hedonic or semantic experimental conditions compared to when consumed with no music. Before the tasting began, each participant was asked what their favorite song was to decide the song for the hedonic condition. Although it is inevitable to account for the varying degrees of pleasure elicited by the chosen song for each subject, it was felt that allowing the participants to self-select their song would more likely invoke a feeling of pleasure during this experimental condition. As for the semantical song condition, the semantically "sweet" song was replicated from a study by Wang et al. (12). Noise canceling headphones (Skullcandyr , Park City, Utah) were used to listen to either the semantic or hedonic music. Each participant first tasted the chocolate without listening to music to establish the baseline sweetness of the chocolate. The baseline score was asked to be rated at a ‘3’ for all participants. Participants were divided into two groups. Each Group 1 participant was then asked to drink water (50 mL with an estimated 2-8 seconds residence time in the mouth) and taste the same make of chocolate while listening to the hedonic song. The participants then rated the sweetness of the chocolate. Subsequently, they were then asked to drink water (50 mL, 2-8 seconds residence time in the mouth) and taste another piece of (the same make) of chocolate while listening to a the semantically sweet music. The participants then rated the sweetness of the chocolate. The order of the hedonic and semantic song was reversed for Group 2 participants. The participants were instructed to drink water between each tasting to eliminate the effect of compounded tastings of the chocolates on the perceptions of the sweetness under each condition. The participants were randomized into the 2 separate groups to reduce the sequential bias of the procedure. Concerning the order of the tastings, it was necessary to have all participants taste the chocolate without any accompanying music before any experimental condition, since this served as a baseline for their perception of the sweetness of the chocolate. Although the song assigned to each condition was played whilst each participant ate the chocolate, the song was also played alone for 10 seconds at the beginning of each condition to allow comprehension of the song alone. This 10 second duration was previously shown to be sufficient to allow processing of the song (4). Compounded with the playing of music during each tasting ensured proper comprehension of music to elicit any cross-modal perceptions. After the chocolate was consumed, the 5-point form was filled out. The 5-point scale was generated from google forms and filled out using the participant’s personal iPhone or school-issued laptop.

Statistical analysis

A comparative analysis (paired Student t-test) was conducted between the scaled responses from the two conditions (hedonic and semantic music).

Results

Scaled responses that indicated changes in the sweetness level of chocolate while listening to the semantic song and hedonic song were recorded (Tables 1 and 2; see Table 3 and 4 for paired responses from each subject). Figure 1 visually depicts the frequency of each sweetness level response from all 52 students, juxtaposing the number responses from both experimental conditions. There were 104 total responses, as each student experienced both experimental conditions. 0% and 1.9 % of all responses of the hedonic song condition and semantic song condition, respectively, felt that the chocolate tasted bitter to the extreme (score of 1) compared to the control condition chocolate taste. 1.9 % of hedonic song responses and 21.6 % of semantic song responses answered with a score of “2”. 28.8 % and 23 % of responses answered with a score of “3”. 40.4 % of hedonic song responses 44.4 % of semantic song responses answered with a score of “4”. 28.8 % of hedonic song responses and 9.6 % of semantic responses answered with a score of “5”. Most participants from both tested conditions felt that the chocolate was sweeter with the (song) stimulus, and the majority of the responses from both conditions responded with a score of 4. Therefore, differences in sweetness level responses between the experimental conditions were more populated at the extreme ends of the scale.

Table 5 presents the statistical significance of the difference between the average values of the sweetness scores of the hedonic and semantic conditions. The results showed that the hedonic condition had a statistically significant higher sweetness level average compared to the semantic condition [3.96 (hedonic song) > 3.38 (semantic song), $p<0.001$], indicating an elevated sweetness perception elicited by the hedonic song. To reduce sequential bias, the experimental method presented half of the participants with the hedonic song and the survey first (Group 1) followed by the semantic song and the rest of the survey. The order of the hedonic and semantic song was reversed for the other half (Group 2). To determine if the order in which the songs were heard affected the results, an unpaired t-test from all the responses of when the hedonic song was presented first versus when it was presented after the semantic song condition was performed (Figure 2). A similar analysis was performed for comparing the semantic song presented first versus when it was presented after the hedonic song condition (Figure 3). In both cases, no significant difference was seen between the 2 groups, suggesting that there was minimal sequential bias in the study.

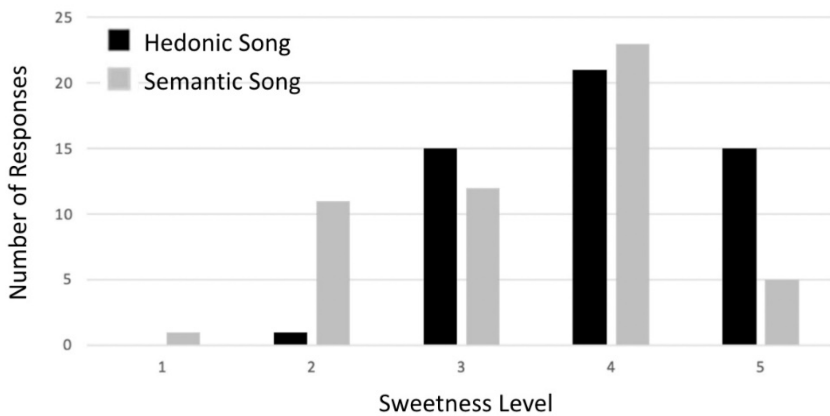
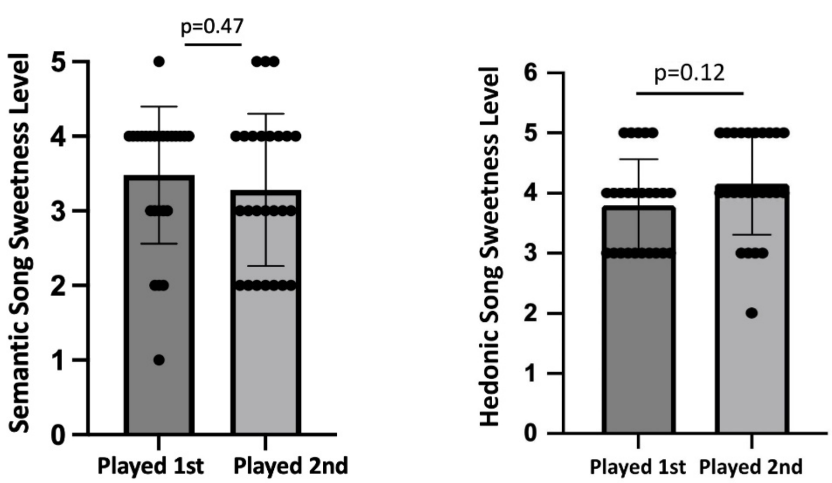


Figure 1. Number of Responses vs sweetness level (Hedonic vs. Semantic) (n= 104).



Figures 2, 3. Unpaired T-test of average value of sweetness level responses when hedonic song is given first vs. last (Figure 2, left) and results when the semantic song is given first vs. last (Figure 3, right).

Discussion

The data from this study suggest that the cross-modal perceptions induced with the hedonically stimulating song were of greater dominance than that induced by the semantically "sweet" song. This was apparent from the 3-fold increase seen in the number of "5" sweetness responses in the hedonic condition compared to the semantic condition and the relative lack of "1" and "2" responses in the hedonic condition (Figure 1). Moreover, a significantly greater number of participants felt that the chocolate became more bitter (less sweet < 3) when listening to the semantic song than when they listened to the hedonic song. Consistent with these observations, there was a statistically significant difference in the sweetness score while listening to the (hedonic) song that the participants enjoyed, compared to the song that had "sweet" (semantic) music qualities (Table 5). These findings suggest that there are differences in relative strength in forming cross modal perceptions with pleasurable "hedonic" music versus the semantically sweet music.

In addition, the "less sweet" responses from the semantically "sweet" song raises some questions, as the results deviate from past studies that have used the same song (7, 18). The deviation can be potentially attributed to the differences in gender and culture of the participants, which is acknowledged to play a factor in the semantical analysis of songs (17, 19, 20). It can also be found that both stimuli were sufficient in inducing some form of cross modal perception. More than half of participants answered with a score that was not "3" for both conditions (Figure 1). On this note, it is important to highlight why the average sweetness scores for both semantic and emotional conditions do not mean that there is "no change" in the taste of the chocolate when the average values are relatively close to the "3" response, since the average score is lowered by the "1" and "2" scores. While the "1" and "2" responses in the 5-point scale do not indicate an increase in sweetness, it does show a change in the flavor, reporting a bitterness of the chocolate. Therefore, the average score value for the responses in both conditions are not indicative of the induction of cross modal perceptions. Analysis of Figures 2 and 3 suggested that the order in which songs were heard did not have a significant effect on active perceptions of sweetness. The finding that the order of the songs does not influence results further strengthens the significance of the responses gathered and, more importantly, reduces the possibility of external bias.

Limitations

The results could have been influenced by the conditions under which the experiment was conducted. Specifically, to comply with the policies of the institution, the researcher was unable to provide blindfolds for the participants while tasting. The ability to see the chocolate would have allowed visual stimuli to influence the outcome of the cross-modal perception, since visual qualities of food have been proven to activate active perceptions surrounding its flavor. The semantically coded song used in the experiment is generally connoted with a "sweet" meaning. However, the metaphorical interpretation may not have applied equally to all participants. Western and non-Western cultures promote different metaphorical associations and symbolic meanings. Bremner et al. reported that those in non-western communities (Zimbabwe) associated chocolate with different properties than those in America (21). The inability to account for differences in cultural identity when collecting participants within the specified age group may have influenced the experimental results by means other than the causation of the active perception, providing a possible explanation for the decrease in sweetness experienced in the semantic song condition (Figure 1). Furthermore, the experimental design led to the lack of a control group/comparison group to be collected. Although the assumption was that the participants would not find any differences in the sweetness of the chocolate in the absence of music, it would have been helpful to account for such data to validate the assumption. Another technical limitation was that the participants did not drink water before tasting the chocolate with no music accompaniment. It is known that water stimulates salivary flow and thus, there are concerns of the variability of water administration on the perceptions of taste (22). However, the absence of water may not have had a significant effect, as it has been reported that there is no effect on perceptions of bitterness and sweetness between low to high salivary flow unless a dry mouth condition existed (5, 23). Thus, the impact of the absence of water may only be apparent when mouth hydration varies at an extreme level (24). Moreover, although water was not provided before the “no music” tasting, this would not impact the results, as the study was designed to compare the sweetness scores only between the hedonic and semantic song condition and not to the “no music” internal control.

Conclusion

The data from this study reveal that cross-modal perceptions induced by the hedonically stimulating song elicited a significantly greater perception of sweetness than that elicited by the semantically “sweet” song. Listening to a song that was emotionally congruent with the food resulted in stronger cross modal perceptions to be formed than listening to one that was semantically congruent. Thus, emotional stimulation was stronger in forming cross modal perceptions between the gustatory and auditory modalities than the semantic stimulation. It is already known that cross modal perceptions are rooted in cross modal correspondences. Thus, it can be assumed that the stronger the cross-modal perception, the stronger the correspondence between the modalities at hand (7-9). Accordingly, it was found that the correspondence between an auditory stimulus and a gustatory stimulus based upon a shared emotion resulted in a greater reinforcement of the latter than one that corresponded to one another based on a shared set of descriptions/meaning. The finding that emotions; rather than meaning; elicited a greater gustatory response should encourage further investigation on the role of emotions within the mechanism of cross modal perceptions. The data also provided several applications to its own study and beyond, such as providing useful data on relationship between the anatomical placement of sensory lobes and cross modal correspondences (25, 26). In addition, retail outlets that include music to induce customers to buy products, can take advantage of the results, choosing “hedonically stimulating” songs to induce customers to buy ‘sweet’ (meant either in a literal or figurative sense) products.

Perspectives

In light of the study's limitations and insights, future research can be framed. As noted before, one of the major limitations of the experimental design was the inability to control for cultural differences. A variant of the experiment that resolves the issue will produce data that is solely due to cross modal interactions between the auditory modality and gustatory modality. Furthermore, an alternative approach to the quantification of the perceptions of sweetness could be conducted, using a sweetness threshold, where the population is given (say) a sucrose solution that serves to be the "baseline" for the experimental perceptions of sweetness. This would have been an alternative method of standardization than having participants create their individual scales by setting the sweetness detected in the no music setting as "3" in the given sweetness scale.

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Appendix

Table 1. Number of responses of each score when hedonic music was provided first

Sweetness scale score (1-5)	Hedonic music	Semantic music
1	0	0
2	0	7
3	10	7
4	1	9
5	6	3

Table 2. Number of responses of each score when semantic music was provided first

Sweetness scale score (1-5)	Semantic music	Hedonic music
1	1	0
2	4	1
3	5	5
4	15	10
5	1	10

Table 3. Individual responses of when the hedonic music was provided first

Subject number	Hedonic music score	Semantic music score
1	5	5
2	3	2
3	4	3
4	3	3
5	5	5
6	5	5
7	4	3
8	3	4
9	4	3
10	3	4
11	4	3
12	3	2
13	3	2
14	3	4
15	4	4
16	4	2
17	3	2
18	5	4
19	4	2
20	3	2
21	4	3
22	5	4
23	4	4
24	4	3
25	3	4
26	5	4

Table 3. Hedonic mean = 3.85, SD = 0.812. Semantic mean = 3.31 SD = 0.95. p = 0.0037 by paired Student t-test (n=26).

Table 4. Individual responses of when the hedonic music was provided after the semantic music

Subject number	Hedonic music score	Semantic music score
1	3	2
2	5	4
3	2	3
4	5	4
5	3	3
6	4	3
7	4	4
8	5	4
9	4	4
10	4	2
11	5	4
12	3	4
13	5	4
14	5	4
15	5	4
16	4	3
17	4	3
18	5	4
19	4	4
20	5	5
21	4	4
22	5	4
23	4	1
24	4	2
25	3	4
26	3	2

Table 4. Hedonic mean = 4.11, SD = 0.831. Semantic mean = 3.42, SD = 0.91. p = 0.00082 by paired Student t-test (n=26)

Table 5. Individual responses for all participants

Subject number	Hedonic music score	Semantic music score
1	5	5
2	3	2
3	4	3
4	3	3
5	5	5
6	5	5
7	4	3
8	3	4
9	4	3
10	3	4
11	4	3
12	3	2
13	3	2
14	3	4
15	4	4
16	4	2
17	3	2
18	5	4
19	4	2
20	3	2
21	4	3
22	5	4
23	4	4
24	4	3
25	3	4
26	5	4
27	3	2
28	5	4
29	2	3
30	5	4
31	3	3
32	4	3
33	4	4
34	5	4
35	4	4
36	4	2
37	5	4
38	3	4
39	5	4
40	5	4
41	5	4
42	4	3
43	4	3
44	5	4
45	4	4
46	5	5
47	4	4
48	5	4
49	4	1
50	4	2
51	3	4
52	3	2

Table 5. Hedonic mean = 3.96, SD = 0.812. Semantic mean = 3.38, SD = 1.04. $p=0.00099$ by paired Student t-test ($n=52$).