Representing flavours with sound

using combinations of sine waves to represent acidic flavours

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Abstract

While science has already proven sound and taste are connected, our research focussed on linking specific sounds to specific flavours. With the help of a peer group five different types of acids have been represented by combinations of sine waves. During our research participants were asked to match the acids with the sounds, in a combination test. Results show that it was relatively difficult to match the sounds with the corresponding acid, but also indicate the relationship of the representation of sound in taste is worth further research.

1. Introduction

In sensory evaluation, flavours have always been described and communicated by means of language. Consumables are described as "sweet", or tasting "like an apple", even by professionals whose job it is to assess taste. While language seems convenient, it is hard to create a universal language based on words to both describe and identify flavours across different cultures and industries. Furthermore, apples taste different in a cold country with apples juicy and sweet compared to warm countries where the apples can be dry and tasteless or non-existent. Also the many varieties in apples (the acidity of a Granny Smith versus the sweetness of an Elstar) make it hard to use the word apple as a flavour descriptor. Still, this is the common language used nowadays, even in science. It is a language that needs to be taught and trained and calibrated.

When we describe basic flavours, we rely on the words sweet, bitter, acidic and salty. Studies have not confirmed (nor really falsified) the existence of just four basic tastes (Erickson, 2008). The use of these four words and concepts, are a barrier in our language to communicate flavour and makes it hard to research if there are just these four basic tastes. This could limit us in describing tastes and flavours. Recently, research posed a fifth flavour, umami, as an additional basic taste (Damak, 2003). Others pose that the range can be even more extensive than four or five basic tastes, hinting that language at this point is not always inclusive (Schiffman, 2000).

Describing taste with language could be subject to linguistic relativity. Kay and Kempton (1984) illustrate that linguistic colour concepts are also culture dependent. It is not just the case that different languages have different words for the same set of colour concepts, but across languages there are different conventional ways of "cutting up" the colour spectrum. These conventional ways are transferred from one generation to the other via the colour lexicon, influencing not only communication about colours, but also perception (see also Berlin & Kay 1969). Similarly, when looking at different languages, words for taste do not always seamlessly translate (. For instance, the words for sweet in Swahili is "tamu". However, this does not literally mean sweet. A better translation would be "good tasting", and by this meaning good tasting food would often be described as sweet. There is no word closer to the English word "sweet" in Swahili. It is likely that this also influences the taste perception.

In the coffee industry, a research program called Word of Coffee Research, created a lexicon describing the flavours in coffee has recently been published[1]. The lexicon describes certain flavour notes in coffee and how to replicate them giving recipes based on tastes and products available in the United States. By doing this the lexicon creates a reference for the flavours described. The reference part is a huge improvement in creating a common reference point for describing the different flavour notes. It goes beyond calibration in sub-work cultures. While the lexicon is a way to solve a local cultural reference problem, it does not solve cross-cultural differences in flavour concepts globally. The lexicon includes the use of fresh fruits, making the reference of flavours less reliable since flavour differences in fresh products occur (e.g. the sweetness of banana versus their ripeness) and also uses the English language to describe the concepts.

Professional tasters need a repeated calibration of flavours. Quality graders (Q-graders) in coffee calibrate flavours, by means of the Coffee Quality institute. This calibration and eventually certification, is to determine what taste in the industry is called sweet, what is acidic and what sort of acids are present in coffees. Future Q-graders also need to correctly identify smells based on an interpretation of smells by Nez du Cafe[2]. The institute describes, especially the identifying smells part, as training your muscle memory. Q-graders get calibrations at least every three years. This to train the muscle memory and get calibrations of intensities right.

At this point there is no cross cultural language to describe flavour concepts. The main language for the Q-graders is English, and the references and training are constructed based on the English linguistic flavour concepts.

An improved, more universal, cross cultural and intuitive way of describing the flavours could help communication and accuracy in descriptors. In this article we investigate if perhaps sound could be replacing language as an intuitive way to describe different flavour compounds.

2. Related works

As the introduction have pointed out the linguistic relativity problems, the question now is why choose sound?

Studies have already confirmed that multisensory experience has an influence on our perception of taste (Delwiche, 2003). The multisensory science field of sound and taste is still young. Studies have been conducted on the influence of sound on human taste perception. There are multiple researches that show a cross-modal correspondence in audio attributes to taste exist. For instance,

1 https://worldcoffeeresearch.org/media/documents/WCR_Sensory_Lexicon_Edition_1.1_2016.pdf

2 https://www.lenez.com/fr/coffrets/cafe

amplifying the sound of chewing can make food appear more crunchy (Zampini, Spence, 2004). The results of these studies can be explained through associations for the taster. Associations playing a role in flavour perception can be learned, and do not in standby hold a universal common reference. As we have learned that more crunchy food sounds more crunchy. Resulting in our perception expects more crunchiness by more sound, apparently even making up for a lack of that when the food is in fact not more crunchy.

Stepping away from a learned association with more obvious sound and taste links, a research by Spence and colleagues (2013) has focussed on matching wines to classic musical pieces. In this study the researchers did not only find a significant association in what particular symphony seems to fit what wine. A more bright wine, would be matched with a more bright harmony and the bright harmony would not match a heavy wine. The research also confirmed the wine tasted more sweet when the matching music was played, and the experience of drinking wine was experienced more enjoyable by the participants, apposed from no music being played at al. This however can be explained by creating a different environment by playing music, which could be perceived by the participants as more enjoyable. It is suggested there exists a spatio-temporal currency with our perception of sound and flavour. Carvalho and colleagues (2016) study showed that soundscapes on different tones can influence the perceived bitterness, sweetness or sourness of beers. Like the research of Carvalho relating researchers all focused on basic tastes and high tones versus low tones. Wesson and Wilson (2010) found that mice displayed supra-additive or suppressive responses when exposed to both odor and audio, opposed to solely being exposed to either sound or odor. Indicating cross-modal interaction in the brain exist between sound and food perception. An much older research suggests that flavours could have a corresponding “perfect pitch” (Holt-Hansen, 1968), introducing specific tastes to a specific pitch. Note that this idea assumes (counter linguistic relativity) that sounds and flavours are linked as a universal human property: only then it could be possible to describe flavours in the form of perfect pitches, as this would would be regardless of calibration and culture.

As pointed out in this section, a fair amount of research has been done in describing basic tastes, like bitter and sweet, with music and soundscapes. However, no research has focused on describing or representing individual flavour descriptors (like lemon, apple or chocolate) using sound. The current article explored non-complex flavours and researched if it is possible to represent these flavours with combinations of sine waves. In other words, we have explored the possibility of representing flavours with audio.

3. Method

3.0 Apparatus & stimuli

We have decided to work from a coffee industry perspective. Five acids naturally occurring in coffee have been used: lactic, malic, phosphoric, citric and acetic acid (see table 1 for a linguistic description of the tastes). These acids are also used to calibrate Q-graders. They differ sufficiently in flavour to be distinguished, but all taste acidic. By only working with acidic flavours our research goes beyond linking acids with just really high notes, as previous studies have been focussing on. This article is a first attempt to focus on the possibility to represent the individual character of the acids with specific (high) notes. The choice for just acids is based on the idea that not just tastes have a matching sound, but each individual flavour compound present in a taste corresponds to an individual pure tone (sine wave).

Acid	Linguistic description
Lactic	The "milk" acid found in cultured milk.
Citric	Acidity found in citrus fruit.
Malic	The acidity of green apples.
Phosphoric	Acidity of soft drinks e.g. cola.
Acetic	The acidity of vinegar.

Table 1: linguistic description of acids used.

The acids were first prepared in a 0.1 M concentration. These concentrations were made by diluting the concentrated acids with distilled water. After this the mixture was more diluted ending with a ratio of 75ml water to 25ml of concentration, making the sample a 0.025 M concentration of the acid. This two-step preparation method is used to prevent huge differences in acidity. Most acids will have a 0.01 concentration increase, when already 1 gram of the diluted 0.1 M concentration of the acids is added. So the two-step preparation methods dilution, is a welcome way for consistency and more precise concentrations.

The dilution was made every hour, to make sure all flavours of the acids are present. Indeed, the trials have shown that the longer the acids have been in the open, the less flavour they contain.

The samples have been tasted at room temperature between 15C and 20C. Research has given evidence that temperature dependence in sensitivity of taste exists (McBurney, Collings, Glanz. 1972, Moskowitz, 1972). Studies vary on what is the best temperature, but generally the consensus is below 34C. Lower would decrease sweetness, but could intensify acidity (McBurney, Collings, Glanz, 1972). The best sensitivity for citric acid according to the research of Cruz and Green (2000) is around 15-20C. Room temperature is optimum for tasting acid, and has a practical advantage to it.

All samples have been tasted in glasses with labels on them relating to the first letter of the acid for recognition. Knowing beforehand what acid are used could trigger memories and emotions which could link to associations in sounds.

The headphones used were from Gerrard St. The headphones were 40mm 32ohm mylar speakers with a range of 10Hz -

20Khz. The volume of the sounds were approximately 70 dB SPL.

3.1 Conducting the sounds

Hypothesizing sound pairing is a universal spatio-temporal phenomenon, the sounds used in the research were conducted with the help of a small group of people, based in sound design and in the coffee industry. The first peer sessions started with drinking coffee and highlighting certain flavours on certain pitches via an oscillator. Different pitches would highlight different flavour notes in the coffee. Peers agreed on what type of flavour note this was: e.g. a sweet vanilla-like note, or a dry burned note. These results indicate that solely focussing on the pitch of a sound was an interesting path for shaping our research.

The next step was, to let peers choose the pitch(es) that to them corresponded with the diluted acids by using an oscillator app [3]. The peers were told they could just pick a single tone, or as many as they would like. The peers all picked multiple pitches for one single type of acid, thus suggesting that creating a sound by combining multiple pitches would best capture the entire flavour profile of the acid.

After deciding the sound should exist of multiple pitches, a new peer group took an individual assessment, tasting the diluted acids. During these sessions, the participants were asked first to visualize the sound in a frequency chart (see image 1). Here, a piece of paper with two axis visualised was given. An x-axis that included the five acids and a y-axis that indicated pitch. Peers were asked to draw the pitches for the different acids, so it would become more clear how the different acids would relate to each other according to pitch. After drawing the frequency chart, the peer group was asked to choose tones (frequencies) via a sine wave oscillator that would match the points in their chart. Participants have indicated being confused during these sessions. They mentioned to focus on good tasting frequency combinations, rather than awful tasting combinations (e.g. sounds making the acid tasting very dry). One of the participants noted that certain combinations highlighted bad tasting flavours. Therefore in the first place the participant did not write them down, while she was only focusing on the nice flavours in the acid. This aspect made determining the corresponding pitches for the different acids more challenging. Everyone has a different background in how they taste and what they look for in flavours and this personal aspect seems to compromise choosing specific pitches for certain acids.

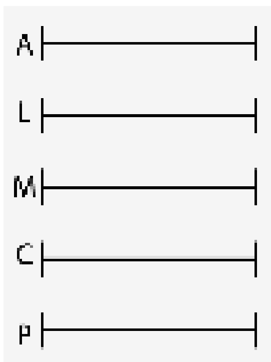


Image 1: the frequency chart used for the individual assessments of the peer group

[3] "The oscillator" app via the App store: https://itunes.apple.com/nl/app/the-oscillator/id640819682?mt=8

The responses were collected and analyzed. While there were some patterns, there were no clearly indicated pitches yet. The focus of our analysis was on which acid was experienced lower or higher in pitch and if there could be a pattern in how different combinations of tones paired with an acid. For instance, do peers make big steps in choosing a pitch, or are the pitches relatively close to each other? Interestingly, one of the responses followed the average patterns quite well. This is why the response of this target peer is used exactly to create the sounds when there was a draw between two pitches. Most people experience pitches relative to each other. The pitch interval between the notes is more important than the exact pitches of the individual notes. It could be the case that the sound and taste relationships have a relative character as well. Therefore, the response of this one peer will be used in order to disqualify (or adjust) different interpretations of pitch.

For acetic acid, most people had a big difference between the lowest pitch recorded and the highest pitch recorded. Another remarkable thing was that most of the participants listed MIDI[4] pitch 103. Other than that, most people only recorded two pitches for the acid. This made it rather simple to pick MIDI pitch 103, and a much lower pitch. On average, the difference between the highest and the lowest pitch is 40 semitones. With the average of 40 semitones lower, there are two clusters of responses with correlating pitches. This was be around either MIDI pitch 67 or 53. The pattern-following peer recorded the pitch at 53, so for consistency this MIDI pitch was be used to conduct the sound. Finally, the sound for acetic acid existed of MIDI pitches 103 and 53.

For lactic acid, a big majority of peers recorded two pitches close to each other in the range from 59 to 82, and an additional, far higher pitch. This higher pitch was most often around MIDI pitch 106. For lactic acid, the pattern-following peer recorded this pattern exactly. Therefore the MIDI pitches recorded by the target peer will be used, being 59.5, 76 and 106. The 59.5 pitch seemed respectively too low and 76 seemed to high, while tasting with a small group of peers. Consequently, the sounds for lactic acid have been altered to 63.5, 74.5 and still remaining 106.

Malic and citric acid have been recorded to be very similar in terms of matching pitches. Most responses had at least one tone quite similar in their response to malic and citric acid. This suggests there is one pitch that should be similar, or even the same, for malic and citric acid. Most responses recorded similar a pitch around 82. This pitch will be used for both malic and citric acid.

For malic acid, a majority of peers recorded an additional pitch a lot higher than the pitch around 82, with pitches between 104.5 and 115. On average, peers recorded 3 pitches for malic acid, but a pattern was hard to recognize. For three

[4] MIDI notes are used as an easier way to express frequencies. They correspond with the white and black keys on a piano. With this oscillator we also had the ability for quarter notes, represented with 0.5 increase in pitch number. A midi note number of 60 corresponds to the middle c on the piano and equals 261.63 Hz. All responses of peers and participants have been recorded in MIDI pitch

peers, the third pitch is close to another pitch. This suggests there is a certain roundness in the overall tone. To keep a bit of the rounded quality of the sound, the lowest pitch is chosen at 104.5.

For citric acid, there is a cluster of responses around MIDI pitch 66, besides the MIDI pitch 82. Hence, these will be the tones for citric acid. While listening to the sound conducted with these two pitches, a small group of peers seemed to be missing a high pitched sound. Therefore, MIDI pitch 111 was added, since two peers have listed that tone too.

Phosphoric acid had the most varied responses, while there seems to be a cluster of responses around 68-72.5. In general, most responses had two pitches relatively close to each other. Where participants had 3 or more pitches recorded, half of them recorded an extra pitch high and half of them recorded the extra pitch low. While focusing on the cluster of responses around 68-72.5, most peers who recorded a pitch in that range recorded an additional pitch close to the pitch and lower. Interestingly, the pattern-following peer is following the pattern of two pitches close to each other in the range of 68-72.5 with an additional pitch far higher. Thus, we chose to follow this response again meaning the pitches used are 69, 72.5 and 113. While listening to the conducted sound with a small peer group, 113 seemed too loud, therefore the specific pitch has been lowered in loudness.

The sounds are online available here: https://soundcloud.com/dagmar-geerlings/sets/audio-representing-acidic-flavours.

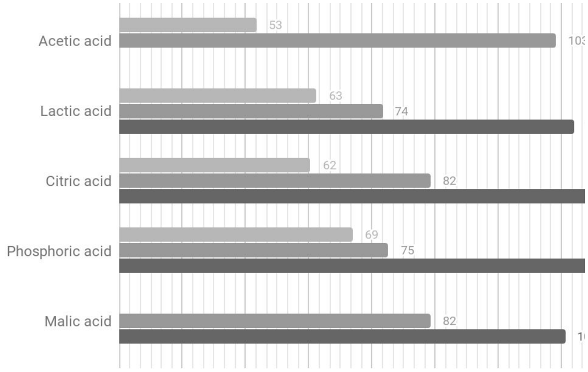


Chart 1: showing the MIDI pitches of all the constructed sounds. The x- axis is showing MIDI pitch numbers, while the y-axis corresponds to the acids represented.

3.2.1 Participants

Participants could voluntarily sign up for the research as a part of their visit to NEMO Science Museum in Amsterdam. Most participants were asked by us to participate. They could also be invited to participate via a screen at the entrance of the research space.
In total, a response of 31 participants was recorded. Participants were aged between 10 and 52 years old; 45% of the participants were female.

3. 4 Design and procedure

3.4.1 Space

The experiment was conducted in a separate room at NEMO Science Museum in Amsterdam.

The research space was a theater room with two identical tables, one per participant.There were two participants tested at the same time, guided by the present researcher. Participants were positioned back to back and wore headphones, so they did not get distracted by each other. The researcher was available for questions during the taste test, hearing tests and visualization of pitches.

The sound in the space was muted, but at times museum noises were present in the space. There is no indication that these interfered with the participants' performance.

3.4.2 Take-in and briefing

After agreeing to participate in the research, the participants were briefed by information in paper-form. Participants were told that the research aims were to find a possible relationship between specific flavours and specific sounds, assuming each of the sounds would represent one of the acids in front of them.

The take-in consisted of two parts. The first part was a sensory test and a hearing test. The sensory test was executed to see if participants could differentiate acids, by means of a triangulation. A triangulation test is a taste exercise where the participants need to pick "the odd cup out". In this case, participants were asked to assess 3 sets of acids. These acids correspond with the acids and concentrations used in the research. Participants needed to successfully pick the three odd cups in the three sets. If participants made one mistake, they were told that one of the sets is wrong. If they could successfully pick the odd set and the matching odd cup, participants could still participate. There was no time limit in this test. After the sensory test, participants were asked to do a hearing test to see what ranges in frequencies they could hear. Participants not able to hear frequencies above MIDI 123.5 (10 KHz) were also excluded from the research, since they could not hear the sounds used properly.

During the second part of the take-in, participants were asked to perform an exercise on flavour-sound pairing. This is done solely with participants who succeeded in the first part of the take-in. The procedure is very similar to the procedure used in the peer sessions to develop the sounds. First, the participants were asked to place the cups with acids in order from a high tone, to a low tone. After this, they were asked to visualize the pitches they would match with the acids on a paper in front of them. No sounds were used during these pre-tests. Participants have been told this is just an exercise, and the results will not be used for the actual research.

3.4.3 Testing

Next, participants were informed that the experiment had begun. They were asked to match a sound with the acids which they think would fit best. The participants used the same cups during the entire research, including the take-in tests.

Assuming the sound representation could also be relative, one of the acids was already presented with a sound. Every participant was told what sound corresponded to malic acid.

When the test started, the acids were filled up to 50 ml. In the briefing, the test was described as a puzzle, where the participants needed to match the flavour of the acid to the sound they reckon would fit best. During the test, participants were seated at a table. On the table was a laptop with headphones attached. The laptop displayed 5 sound samples, including the reference sound for malic acid. Participants were encouraged to place the cups in the order that correlated to the sound samples visualized on the screen. They could click on each sound to listen to it as often as they wanted.

When tasting for instance wine and coffees, professionals normally are making a slurping sound assessing the coffee. Some of the participants might have been familiar with this practise, however the participants were asked not to do this since it creates a sound (and possibly a pitch) which could interfere with the research.

There was no time limit for participants, the only limitation was the sample size of the acids, which was 50 ml per sample. The buttons were presented in a randomized order (changed twice a day, for over 4 days in total) with numbers on them. The samples were also in a randomized order with a letter on them. The letters were the first letter of each acid.

After participants indicated they had finished the task, the researcher assisted in the process of filling out the form indicating which sound matches which acid. After the test, age and gender were written down as well as any further remarks.

4. Results

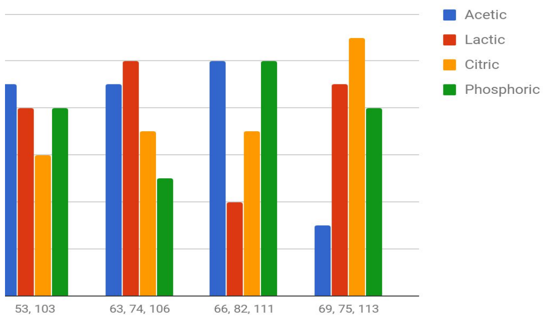
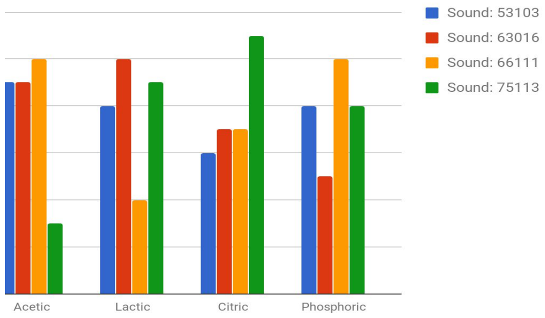


Table 2 (above) and 3 (below) visually representing the obtained data. Table 1 shows what acids are matched to what sound. Table 2 shows what sounds are matched with what acid. The intended match is represented with the same colour in the chart: blue is MIDI pitch 53, 103 and acetic acid; red is MIDI pitch 63, 74, 106 and lactic acid; orange is MIDI pitch 66, 82, 111 and citric and MIDI pitch 69, 75, 113 and green are phosphoric acid.



For all tests a significance level of $p<0.05$ was maintained unless indicated otherwise. It was hypothesized that the sounds that were created to correspond to a specific acid would be matched to that acid significantly more often than to any of the other acids. When looking at which sound is paired with which acid, regarding the overall sample size ($n = 31$), there was no significant effect in the data. These results were calculated using a chi-square test.

The likelihood of a random distribution of acids matched with sounds provided a *p*-value of 0.335. In Table 2, the data was visualized in a graph indicating which acid is matched to which sound and in Table 3, the same data was used to indicate which sound is matched with which acid. There is a small but insignificant trend (maintaining $p<0.05$) with all participants when we look at what acid has been matched less often to a sound. The sounds for acetic acid (MIDI pitches 53, 103) did not match citric acid. The sounds for lactic acid (MIDI pitches 63, 74, 106) did not match phosphoric acid. The sound for citric acid (MIDI pitches 66, 82, 111) did not match lactic acid. Lastly, the sound for phosphoric acid (MIDI pitches 69, 75, 113) did not match acetic acid.

Interestingly, only in the cases of acetic and lactic acid, the sounds were correctly matched by a majority of the participants.

Considering every sound had an initial matching acid, the data has also been analysed to see what acids have been paired with their initially intended audio. This is again done via a chi-square test. Results show that lactic and acetic acid were significantly more often matched to the 'correct' audio file (p=.025 and p=.002 respectively). This however is not the case for citric and phosphoric acid (p=.079 and p=.095 respectively). This could suggest the sounds for phosphoric and citric acid have been conducted in a less clear and straightforward way by the peers.

Overall, a number of participants noted that it seemed pretty logical and intuitive to match a sound with an acid. Additionally, a lot of participants noticed that the flavour of the acids changed with the different sounds. Some people indicated they were considering swapping two of the acids matching a different sound. In most cases, participants mentioned one of the acids they might swap with another as lactic acid. It varied with what acids they would swap it. Similar to the peer sessions, two participants noted that the sounds as they imagined them were pitch-changing sounds. Two other participants noted that if they would like the taste of an acid, they would pick a sound they liked better also.

5. Discussion

5.1 Influences on taste

Mood is not taken into consideration for this research, although it has been proven to influence the way we perceive flavour. Seo and Hummel (2012) used the sound of a laughing baby and a crying baby while letting people smell pleasant and unpleasant aromas. Results indicated that smells would be more pleasant when a laughing baby sound was present, regardless of the actual pleasantness of the smell, and vice versa. That does not necessarily mean it would affect how people would pair the acids differently. However, if people would perceive a sound as more pleasant, they might pair them with acids they perceive as pleasant as well. Some of the participants have actually mentioned this during the research.

5.2 Relative or absolute mapping

The pitch of a sound is perceived relatively. Some acids had a lot of responses in the exact same pitch during the peer sessions. Thus it is unclear if the sound representation could be relative too. The current research has noted this option and therefore has given all participants a reference sound for malic acid. However, our research did not study the relative nature of sound in relation to taste.

Add here that the design in which people had to 'puzzle' acids and sounds together is such that it exhausts the possibilities in a hypergeometric distribution. Reanalysis of the data using more advanced statistics, taking that into account, may show more patterns than you have now isolated using simple tests for the numbers of matches and non-matches

5.3 Understanding the assignment by peers

It could perhaps be that there has been a division in how well participants understood the assignment. Although participants were told not to pick the sounds that makes an acid taste nice but which one it represented, it is hard to check if participants indeed did this. What makes this research difficult, is that the participants always worked in combinations. Meaning if, as the data shows, two of the sounds representing two different acids are poorly conducted they could influence the position of better matching acids. Indeed, since this research is the first to attempt to conduct sounds representing specific acidic flavours, it is plausible that better sound representations of the acids are possible. It would be interesting to see how people respond to just acetic acid and lactic acid in a following research to see if people would find it easier to match.

6. Conclusion

6.1 Conclusion

The data showed that it was relatively difficult to match the sounds with the corresponding acid. However, data supports the theory that acids can be matched with specific sounds, since two acids could be quite accurately be assigned to the corresponding acid, while two other sounds failed to represent the intended acid. This conclusion follows from the analyses. It shows that when participants have matched a sound to an acid as intended, it is likely these acids would be lactic and/or acetic acid. A similar level of significance is not found with phosphoric acid and citric acid. This indicates the relationship of the representation of sound in taste is worth further research, but fails to make a bold statement.

6.2 The properties of the sounds

While the data shows the sounds for lactic and acetic acid somehow are better conducted to make participants choose the corresponding acid, it is hard to logically explain why this is the case. Especially since people noted that they would link nicer sounds (harmonious or dissonant) to "nicer acids", it is interesting to note that acetic acid, a generally unfavourable acid, has been matched with a harmonious sound. Alternatively, lactic acid has been conducted with an inharmonious sound, despite lactic acid not being particularly liked or disliked in taste.

During the peer sessions and during the research, some of the participants said, while tasting, their imaginary matching pitch was moving: a pitch-changing sound. A following iteration of this research could take this into account.

7. Future research

<u>7.1 Using the data for new iterations</u>
Looking at the data (i.e. what sound people matched to what acid: see Table 2), it is interesting to see acetic acid does not get represented with the sound constructed for phosphoric acid. It could prove relevant to reconstruct the sounds using this data. There is a strong trend for citric acid being better represented with the sound for phosphoric acid.

More experimentation with conducting the sound is necessary to find auditive representation of flavours in a distinctive way.

<u>7.2 Linking aroma phenomena to taste phenomena</u>
Wright (1977) poses the theory that aroma might be recognized within our olfactory senses by molecular vibrations. While this theory has not been sufficiently supported by other research, it could be interesting to see if this could also account for taste. Other research suggests sound can alter the human perception of smell (Peeples, 2010). Assuming same systems are used to translate our perception of taste, it would not be surprising to find a connection between the two phenomena. For future research, it would be interesting to see if the molecular vibrations could be translated into sounds, and if that would make a better fitting composition. However, temperature might become more important in this matter, because molecules vibrate more in warmer environments.

<u>7.3 Scientific research in flavour attributes</u>
To date, there is no scientific measurement to properly conduct sensory science research regarding flavour attributes other than triangulation tests. Naming flavour attributes need calibration, and therefore requires trained professionals. Since the theory of representing flavours with sounds is supported to some degree by the current paper, designing a mapping system to qualitatively conduct flavour research seems a feasible outlook.

Regarding the experience of this research we would hypothesize it is possible to create a mapping system which can highlight flavour notes in consumables with audio samples. If indeed a highlighted flavour is experienced, it would mean the flavour is present. If no highlighted flavour is experienced, it would mean the flavour is not present. This would not only make flavour attributes in sensory science more reliable, it could also open up the entire field. We would not need professionally calibrated tasters anymore. Studies can benefit, not only by practical manners by a much better availability of untrained regular participants, additionally this would be more closer to the flavour experience and perception in a general way.

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