Eating Like an Astronaut: How Children Are Willing to Eat "Flying" Food Using Acoustic Levitation

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ABSTRACT

How food is presented and eaten influences the eating experience. Novel gustatory interfaces have opened up new ways for eating at the dining table. For example, recent developments in acoustic technology have enabled the transportation of food and drink in mid-air, directly into the user's tongue. Basic taste particles like sweet, bitter and umami have higher perceived intensity when delivered with acoustic levitation, and are perceived as more pleasant despite their small size (approx. 20μL or 4mm diameter droplets). However, it remains unclear if users are ready to accept this delivery method at the dining table. Sixty-nine children aged 14 to 16 years did a taste test of 7 types of foods and beverages, using two delivery methods: acoustic levitation, and knife and fork (traditional way). Children were divided into two groups: one group was shown a video demonstrating how levitating food can be eaten before the main experiment whereas the other group was shown the videos after. Our results showed no significant differences in liking of the foods and beverages between the two delivery methods. However, playing the video prior to the test significantly increased the liking and willingness to eat vegetables in the levitation method. Evaluative feedback suggested that a bigger portion size of levitating foods could be the game-changer to integrate this novel technology into real-life eating experiences.

CCS CONCEPTS

• **Human-centered computing → User interface design**; *Interaction design*;

KEYWORDS

Taste; Food Interaction Design; Acoustic Levitation; Food Delivery System; Taste Perception; Children Eating Behaviour

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1 INTRODUCTION

The field of Human-Computer Interaction (HCI) has traditionally focused on the use of visual and auditory modalities when designing user interfaces. This has changed with recent research linked to the study of food in everyday life (e.g., [12, 21]), the ecologies of domestic food consumption and product design [38]. There is an emerging trend in the exploration of novel interaction concepts for eating [43] like shape-changing food [48] and edible interfaces [11].

Figure 1: Participants in a group of five people during a hands-on levitation activity where they levitated and tasted different types of foods and beverages.

Recent applied research in acoustic technologies has shown great potential to further transform the exploration of the sense of smell and taste. For example, the TastyFloats system [44] can successfully levitate liquid and solid food morsels taking into account the ambient temperature, the characteristics of the food items, and its effect on taste perception. It has been reported that perceived taste intensity (sweet, bitter, and umami) was higher when tasted in a levitation condition than in a non-levitation one. Also, the hedonic quality of the bitter taste was modulated in the levitation condition, making it a less unpleasant taste. The upgraded version of TastyFloats, called LeviSense [46], is the first platform that incorporates the stimulation of five human senses (taste, smell, vision, hearing and touch) in the context of levitating food. These platforms can be used as innovative tools for chefs to present their dishes, or to help customers to ingest bitter but healthy food (e.g., broccoli or codfish oil) encouraging the consumption of vegetables in children.

However, it has never been tested if customers, especially children, are willing to accept acoustic levitation as a food delivery method on their dining table. To answer this question, we conducted a user study with children to contrast the two distinct delivery methods: acoustic levitation (i.e., with TastyFloats), and traditional eating method (i.e., using cutlery). Our results provide the first empirical insights on how children are willing to eat levitating foods. Based on the findings, we give suggestions to human-food designers and researchers on adapting this novel interactive platform to the dining environment.

2 RELATED WORKS

2.1 Gustatory interfaces in HCI

In recent years, human-food interaction has attracted a growing interest in HCI. This is evidenced by a proliferation of gustatory interfaces that computationally enrich the interaction between human and foods. For example, EdiPulse [28] offers playful reflections on everyday physical activity through the appealing medium of chocolate. Similarly, GustaCine [29] offers an engaging crossmodal cinematic experience that allows the viewer to experience and savor cinematic moments through the gustatory pleasures of the different flavoured popcorn. LOLLio [33] is designed as an interactive lollipop that serves as a haptic input device that dynamically changes its taste. TasteBud [45], is a plug-and-play gustatory interface that provides an interactive and flexible gameplay using taste stimuli. A brief summary of gustatory interfaces can be found in [43].

Recently advances in acoustic levitation has demonstrated that that food morsels (small pieces of solid food) or droplets (liquid drops) can be levitated in mid-air (e.g., [1]), transported and deliver to the user's tongue (i.e., TastyFloats [44]). This type of gustatory interface offers a novel way of eating without cutlery, therefore leaving the user's hands available, and changes the taste perception of the levitated food (i.e., sweet, bitter, and umami tastes). Another system, LeviSense [46], provides the first platform for multisensory integration in gustatory experiences based on levitated food. Their user studies on the influence of lighting and smells on taste perception of levitating sweet showed a clear interaction between the senses, and demonstrate the possibility to create an immersive eating experience with levitating food.

Despite the limitation in size of the levitating food particles (around 4mm in diameter), the introduction of acoustic levitation-based food delivery systems, such as TastyFloats and LeviSense, has the potential to inspire and provides guidance on how to design novel gustatory interfaces. Because levitating food has its hedonic quality modified (i.e., sweet becomes sweeter and bitter becomes more pleasant), these devices can help customers to ingest bitter food but healthy benefits (e.g., broccoli), providing users with a less uncomfortable experience (e.g., encouraging the consumption of vegetables or fish oil for children). However, this is based on the assumption that customers, especially children, are willing to try and accept these devices (or acoustic levitation delivery method) on their dining table.

2.2 Key challenges in children's food preferences that HCI might address

It has been established that fruit and vegetables are an important dietary component, especially for children. This is because they include the vital micronutrients which have a major role in disease prevention [37, 41]. Despite that, it has been shown that less than half of American children meet their daily recommended intake of fruit and vegetables [22]. Similarly, it was shown that Norwegian children and adolescents eat less than half of the recommended 5 portions of fruit and vegetables per day [24]. Possible reasons that cause lower fruit and vegetable intake in children are less exposure to vegetables in childhood or at home [47], food neophobia (reluctance or avoidance of trying new foods) [2] and food pickiness (resistance to eat unfamiliar foods) [16]. However, taste preferences and liking for fruits and vegetables are the most important reasons for low fruit and vegetable consumption in children and adolescents [6, 8, 10]. Particularly, the most influential reason that deters vegetable consumption is its bitter taste [15] which is naturally associated with most natural poisons [20] and is pre-programmed to be rejected by humans [7]. Other less influential reasons for lower liking for vegetables include their unpleasant texture [49] and low energy content [19].

Several strategies have been proposed to encourage fruit and vegetable consumption in children, such as increasing portion size [40]; giving incentives to children to encourage them to eat more fruits or vegetables [5, 13]; or using flavour learning to increase children's liking of vegetables [23]. A large number of studies have now been conducted using a wide variety of behavioural strategies to try and encourage greater acceptance of fruit and vegetables in children (reviewed in [14, 35]). Analyses of these studies clearly identify that the most effective strategy is to increase exposure [4, 34]: the more familiar these foods become, the more children are willing to eat them. But encouraging children to try and consume foods which they are wary of is challenging for parents. Here, HCI designers can harness the advances in human-food interaction to design novel gustatory interfaces that improve the palatability of vegetables or enhance their eating experiences. This consequently increases the familiarity of fruits and vegetables by making the exposure experience more interesting and playful [32].

Using technology to improve positive eating behaviour in users, especially children, has been a growing interest in HCI. For example, FoodWorks [17] uses augmented reality to digitally augment a plate of food and provide rewards for finishing a meal. Similarly, Leem et al. [30] presented a mealtime assistance system using magnetometer and speech recognition (MAMAS) to analyse parent-child interaction, to promote children's healthy eating habits. Joi et al. [26] presented an interactive and connected tableware system to encourage children to eat more vegetables and learn about their benefits. Notably, as well as increasing exposure to fruit and vegetable flavours, levitating food has the potential to address a major reason for low vegetable consumption in children, as it offers a less bitter taste and a playful magical experience. However, this needs an in-the-wild study to evaluate children's willingness to have such devices as part of their eating experience. Also, as this is a novel way of eating without using cutlery, how to present the devices and "teach" children to be familiar with the experience needs to be examined.

3 TASTE EXPERIMENT

This study investigates how children are willing to eat levitating foods using TastyFloats, compared to traditional method using cutlery. Children are given the TastyFloats device to levitate and taste different foods and drinks, then compare their liking and comfort with the normal way of eating using cutlery. Additionally, this study examines how the use of videos to demonstrate to children the new eating experience influences their liking of the tasted foods and drinks.

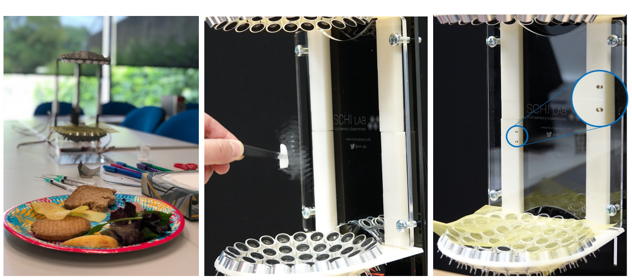
3.1 Study design

We conducted a mixed-design experiment, comparing:

- 7 types of foods and beverages: vegetable/salad, ham, crisps, biscuits, apples, milk, and cheese.
- 2 delivery methods: acoustic levitation using TastyFloats and traditional method on a plate.
- 2 conditions: in one condition, participants were shown a video demonstrating how levitating foods can be eaten before the main experiment started (the *"Video before" condition*) while in another condition, participants were not (the *"Video after"* condition).

Sixty-nine children (31 males, 38 females) aged 14-16 years (M = 14.94, SD = 0.29) participated in the experiment and were divided into four groups. Each group had a size of 17-18 children and participated in one workshop. The workshops were advertised as part of an activity to introduce young children to science and technology.

Taste stimuli: Seven common foods and beverages sourced from a local supermarket (©Co-op Food, UK) were used: vegetable/ salad (Co-op Baby Leaf Salad 115g), ham (Co-op Honey Roast Ham 220g), crisps (Tyrrells Lightly Sea Salted Potato Chips 150g), biscuits (McVitie's Digestives Original Biscuits 400g), apples (Co-op Great British Apples 4 Pack), milk (Co-Op British Fresh Whole Milk 1 Pint/568ml), and cheese (Leerdammer Original Dutch Cheese 8 Slices 160g) (see Figure 2a).



(a) (b) (c)

Figure 2: (a) Selected foods given to children in a hands-on food levitation activity; (b) Visualising standing waves using dry ice; and (c) 2 droplets of levitating juice.

Demonstration Videos: Participants were shown four video clips during the workshop. Of the four video clips: clips 1 & 2 were shown at the beginning of the workshop, clips 3 & 4 were shown at different times depending on the condition of the group.

- **Clip 1**: *"British Astronaut Tim Peake shows how to drink water in space"* (https://youtu.be/6fXKtJcile8): to attract attention and set an inspirational theme for the workshop.
- **Clip 2**: *"TastyFloats: A Contactless Food Delivery System"*: showing system design and levitation of droplets (https://youtu.be/ZQxgBs0mFPA).
- **Clip 3**: *"Presenters Are Amazed by the Taste of Floating Food! | Good Morning Britain"*: a live demonstration of how food and beverage morsels were levitated and eaten on iTV UK channel (https://youtu.be/sSglcz8TIAU).
- **Clip 4**: *"TastyFloats on BBC Clicks! Up, Up, and Away!"*: demonstrating how food and beverage morsels are eaten in a BBC Clicks! documentary (https://youtu.be/4Nh_i3Gb-Yo).

3.2 Procedure

The experiment was divided into four workshops, each with a group of 17 participants. There were three TastyFloats units available in each workshop. Therefore, upon arrival, participants were separated into 3 sub-groups, each was assigned to a station with one TastyFloats unit (see Figure 1). The experiment consisted of three activities.

Activity 1: All participants in the group were first shown video clip 1, showing British astronaut Tim Peake demonstrating how to drink water in space, to set a theme for the event. They were then explained verbally by organisers about how the device works, as explained in [44]. Then, video clip 2 was shown, illustrating the underlying technology and design of TastyFloats. Afterwards, each sub-group experimented with dry-ice fog to visualise the standing-wave patterns inside the levitator (see Figure 2b) and practised levitating polystyrene beads.

Activity 2: Once all participants had learnt how to levitate polystyrene beads, they started with actual food items. Each participant was handed a questionnaire, asking them to compare: liking (*"How much do you like the [food/ beverage name]?"*) and comfort (*"How comfortable do you feel in tasting the [food/ beverage name]?"*) of each food item (using a 7-point Likert scale from *1 = Not at all* to *7 = Very much*), with each delivery method: levitation and traditional, in the latter they tried it on a plate with cutlery. Participants in the last two workshops were shown video clip 3 before the activity (the *Video before* condition), but participants in the first two workshops watched the same video clip (#3) at the end of the workshop (after activity 3 - the *Video after* condition).

Activity 3: Participants levitated beverage droplets. There were three shot glasses of milk, apple juice, and water. Participants were demonstrated how to levitate liquids, then tried to replicate this using 1ml syringes (with blunt needles - attached to the syringes in Figure 2a & c). Using the same questionnaire as in activity 2, they were asked to rate their liking and comfort for milk. Similar to activity 2, participants in the last two workshops were shown video clip 4 before starting the activity (the *Video before* condition), whilst participants in the first two workshop watched it after this activity (the *Video after* condition).

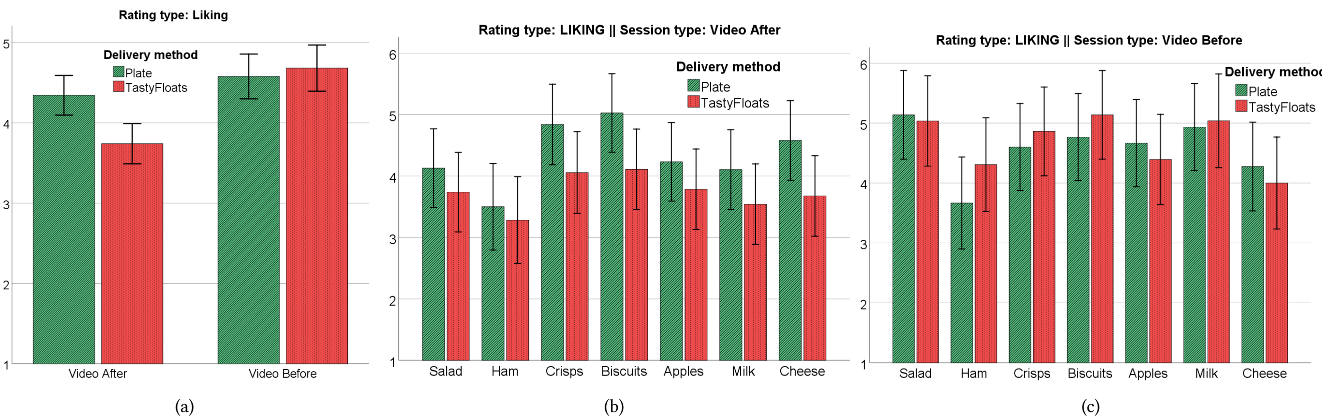


Figure 3: Average food liking ratings of foods and beverages split by: (a) condition (Video after vs. Video before) and delivery methods (Plate vs. TastyFloats); (b) & (c) difference in food liking between the two conditions in each food type.

Finally, participants were asked two questions: (1) which delivery method they liked more to eat vegetables (*TastyFloats* or *Traditional*), and (2) what would be an ideal dish for the levitation delivery method (write down the name of the dish and if possible, its description).

4 RESULTS

We used univariate ANOVA to analyse the rating scores, with independent variables of delivery methods, conditions (or sessions - showing video clips before or after each activity), and food types. The results of each rating type: food liking and tasting comfort are reported separately below.

4.1 Liking

Overall, we found no significant differences in food liking between the two delivery methods: plate vs. TastyFloats ($F_{1,13.98} = 3.39, p = 0.66; M_{plate} = 4.46, SE = 0.10; M_{TastyFloats} = 4.21, SE = 0.10$). There was a significant difference between session types: showing the video clips before the activity resulted in higher food liking ($F_{1,77.48} = 17.78, p < 0.001; M_{video\ before} = 4.63, SE = 0.10; M_{video\ after} = 4.04, SE = 0.09$).

There was also a significant interaction between Session and Delivery methods, ($F_{1,28.03} = 6.79, p < 0.01$). Specifically, in the *Video after* condition, food liking in the TastyFloats delivery method (M = 3.74) was significantly lower than in the plate method (M = 4.34) ($t_{248} = 3.39, p < 0.01$, see Table 1 and Figure 3c). This difference was not found in the *Video before* condition ($p > 0.5$).

Similarly, we found a significant difference in food liking between video conditions for the TastyFloats delivery method: *Video after* (M = 3.74) and *Video before* (M = 4.68) ($t_{177} = -4.36, p < 0.001$, as illustrated in Table 1 and Figure 3a). Figure 3b & c also show the changes in food liking between the two conditions (*Video before* & *Video after*) of each food type.

4.2 Comfort

Univariate ANOVA found a significant difference between the two delivery methods (TastyFloats vs. plate) ($F_{1,207.83} = 43.97, p < 0.001$). Paired t-tests in each condition (*Video after* and *Video before*) showed significant differences between these two delivery methods: tasting foods and beverages from a plate was significantly more comfortable than with TastyFloats ($p < 0.001$) (see Figure 4 and Table 1 for more details). No significant difference

	LIKING		**COMFORT**	
	Video before	Video after	Video before	Video after
Plate	4.58 ± 0.14	4.34 ± 0.13	4.40 ± 0.15	4.47 ± 0.13
TastyFloats	4.68 ± 0.15	3.74 ± 0.13	3.47 ± 0.16	3.48 ± 0.14

Table 1: Mean ratings (± SE) of food liking and tasting comfort in the two delivery methods (Plate vs. TastyFloats) and in each condition (Video after vs. Video before).

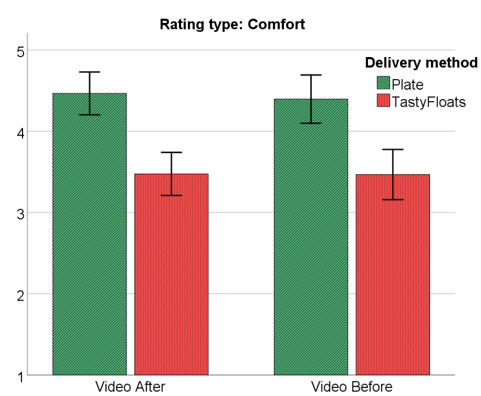
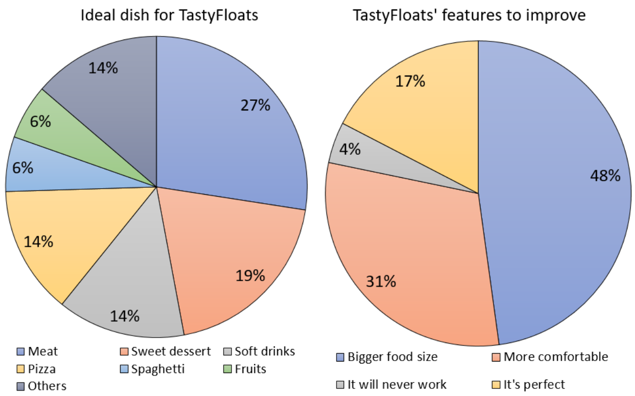


Figure 4: Average rating scores ($\pm SE$) of tasting comfort across the 7 types of foods and beverages.



(a) (b)

Figure 5: (a) Ideal dishes for TastyFloats, and (b) most wanted features on TastyFloats.

was found between the two conditions (*Video after* vs. *Video before*) ($F_{1,0.34} = 0.07, p = 0.79$). No significant interaction was found between conditions and delivery methods.

4.3 Eating vegetable and ideal dish for TastyFloats

We performed a paired t-test to compare the scores of *"willing to eat vegetable"* using each of the delivery methods. No significant difference was found between TastyFloats ($M = 5.10 \pm SD = 0.37$) and plate ($M = 5.41 \pm 0.41$) ($p = 0.49$).

On the comment of an ideal dish for TastyFloats, participants were excited to have daily common foods on their dining tables, such as meat (i.e., ribs - 27%), sweet dessert (i.e., cakes - 19%), soft drinks (i.e., juices - 14%), pizza (14%), spaghetti (6%), fruits (6%), and others (14%) (see Figure 5a).

When being asked about what would be the "game-changing" factor for having TastyFloats in the context of eating and tasting, about half of participants (48%) were eager to have bigger pieces of food levitated. Consistent with the finding that it was not as comfortable to taste foods as with a plate, 31% of participants wanted the device to be more comfortable to use. Interestingly, 17% of participants thought the device would already be ready to use on the dining table, while 4% of participants did not anticipate the device to work in a dining environment and did not wish to use it in their home (see Figure 5b).

5 DISCUSSION

In this work, we present the first study to investigate children's perception and willingness to accept levitating foods and beverages.

5.1 Liking and comfort in using TastyFloats

Our results show that children found tasting foods and beverages not as comfortable as in the traditional manner (on a plate). One main reason was because the unit given to them was only to levitate food and drink morsels. This required participants to actively take the levitating morsels inside the devices, resulted in a less convenient eating manner. A better approach would be incorporating the transportation unit, as presented in [44] or the full multisensorial platform (LeviSense [46]) where foods morsels are transported directly onto the participant's tongue.

Despite being less comfortable, participants found tasting food and beverage morsels using TastyFloats equally pleasant as the traditional method (i.e., on a plate for solid foods or using a cup for beverages). This is encouraging to apply further improvements to this novel delivery method. Specifically, it is possible that if levitating foods are designed to be eaten more comfortably, the pleasantness would be higher, potentially higher than the traditional method. This is in-line with previous findings in [44] where participants found levitating droplets (i.e., of sweet and bitter) tasted more pleasant than when having the same droplets directly dropped on their tongues.

5.2 Using video instructions

Our results show that it is beneficial to demonstrate to children previous examples of other people tasting foods and drinks, especially from familiar figures (i.e., TV presenters). We found significant higher food liking, albeit the same level of comfort, when children had viewed the demonstrating video clips before the tasting activities. It could be understood that showing the video clips is similar to giving children the "peer-modelling" needed for them to accept the new foods [9]. This is an important lesson for human-food designers or chefs in using acoustic levitation to levitate foods and beverages on a real-world scenario (i.e., on a dining table). Incorporating these instructional video clips should be a part of the tasting experiences, and should be done prior to the activity.

5.3 Co-designed flavours using material food probes design method

The four workshops in this study are an illustration of the *material food probes* concept, defined by Gayler et al. [18] as a design method to uncover opportunities for both design-with, and design-around food in the context of intimate relationships. Here, a group of participants can collaborate and focus on the provided food materials' taste, texture, and colour to co-design their unique flavours, which is later used for the specific purpose of supporting emotional communication (similar to *material probes* [27]). Food materials are explored, arranged, and then co-designed using TastyFloats. The arrangement of foods carries strong personal meaning and interpretation to that specific group of participants. This step also represents the similarities with the *technological probes* concept as defined in [25].

5.4 Future work

In this work, participants were introduced to new delivery methods. Hence, it is possible that participants were more excited to try the new tasting experience. A follow-up work should investigate how the taste perception in terms of liking and comfort changes when participants are already familiar with the delivery method.

It should be noted that the food and beverage morsel's size was constrained by the technology limitation, the maximum size was about 4mm in diameter, albeit multiple morsels can be levitated and tasted at the same time. Future investigations can harness further advance in acoustic technology to increase the size of levitating particle (as in [3, 31]), consequently improving user's tasting experiences.

In the present experiment, we investigated children's perception of foods and beverages, but only attending to taste. However, eating is a multisensorial experience, that involves all of human senses [36, 39, 42]. Therefore, future investigations should involve more senses (i.e., vision, smell, and touch) in the investigation, and use an appropriate platform for this task such as LeviSense [46].

6 CONCLUSION

We conducted a study with 69 children to investigate their taste experience (i.e., liking and comfort) of eating levitating foods and beverages. Our findings support the potential benefit of designing levitation-based gustatory interfaces in the field of human-food interaction, as well as in real-life scenarios (i.e., on a dining table).

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