Demonstration of FoodFab: Creating Food Perceptual Illusions using Food 3D Printing

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Abstract
Food 3D printing enables the creation of customized food structures based on a person's individual needs. In this paper, we demonstrate the use of food 3D printing to create perceptual illusions for controlling the level of perceived satiety given a defined amount of calories. We present FoodFab, a system that allows users to control their food intake through modifying a food's internal structure via two 3D printing parameters: infill pattern and infill density. In two experiments with a total of 30 participants, we studied the effect of these parameters on users' chewing time that is known to affect people's feeling of satiety. Our results show that we can indeed modify the chewing time by varying infill pattern and density, and thus control perceived satiety. Based on the results, we propose two computational models and integrate them into a user interface that simplifies the creation of personalized food structures.

Author Keywords
personal fabrication; food perception; food-interaction design; food 3D printer; fabrication techniques

CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI);** *Interaction design;*

Introduction

Recently, food perception researchers have started to investigate how to change people's perception of satiety by modifying perceptual cues. Visual cues, for instance, play an important role: When a piece of food is cut into strips rather than cubes, people perceive it as more filling since it takes up more volume on the plate [3]. Similarly, haptic cues, such as an increased biting force and the resulting longer chewing time affect people's feeling of satiety [4].

Within HCI, we see a growing effort to implement such perceptual cues digitally by overlaying content onto the food using augmented reality [2]. While augmented reality delivers effective illusions, it requires users to wear extra hardware and is less practical when used at home since users see the plain food before it is augmented.

With the proliferation of food 3D printing technology, the creation of computationally-controlled food perception illusions is no longer limited to the digital realm but can be tied back to the physical modification of food, which was originally used in food perception research.

FoodFab: 3D Printed Food Illusions

FoodFab is a food 3D printing system that prints food which induces different levels of satiety given a specified amount of calories. It accomplishes this by modifying the chewing time of the 3D printed food, which has been shown to correlate with satiety. FoodFab creates food structures of specific chewing times by varying two 3D printing parameters: the *infill pattern* and the *infill density*.

We chose to modify infill for two reasons: (1) variations in infill allow to vary the mechanical strength of the 3D printed food structures, which causes the changes in chewing pattern and time, and (2) variations in infill are not visible from the outside, i.e. hidden from the user.

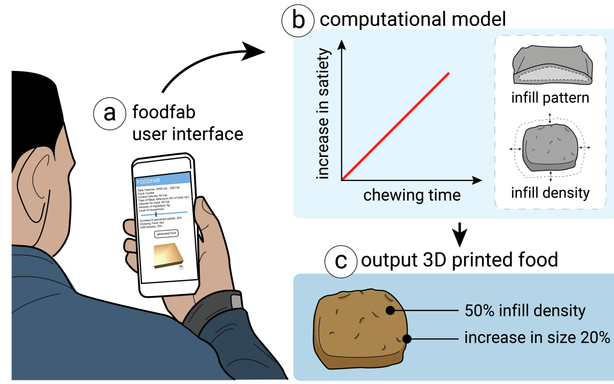

Figure 1: FoodFab is a system that controls a person's perceived satiety given a defined amount of calorie intake. It accomplishes this by creating food structures of different chewing times, which can be accomplished by varying 3D printing parameters, such as infill pattern and infill density. (a) Users input the type of food and level of hungriness, (b) FoodFab retrieves the required chewing time and matching infill parameters, and (c) 3D prints the food.

Infill Pattern: Infill patterns, such as honeycomb, rectilinear, and Hilbert, change how the infill path is laid out (Figure 4). The type of infill pattern affects the chewing time but does not affect the calorie amount since the path of each infill pattern is approximately the same length and thus requires approximately the same amount of ingredient.

Infill Density: Infill density defines how sparse the model is on its interior (Figure 3). The density of infill affects the chewing time since sparser structures have less mechanical strength. Since lower infill densities require less ingredient, the model is enlarged to keep the calorie amount constant for different densities.

To create a piece of food that induces a desired satiety level given a defined calorie amount, the FoodFab system takes

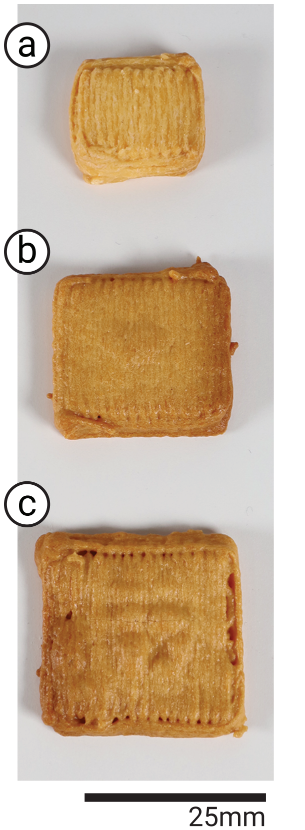

Figure 3: Varying infill density, which also varies size: (a) 70% infill (25x25mm), (b) 55% infill (35x35x5mm) and (c) 39% infill (40x40mm). All cookies are printed with 5mm height.

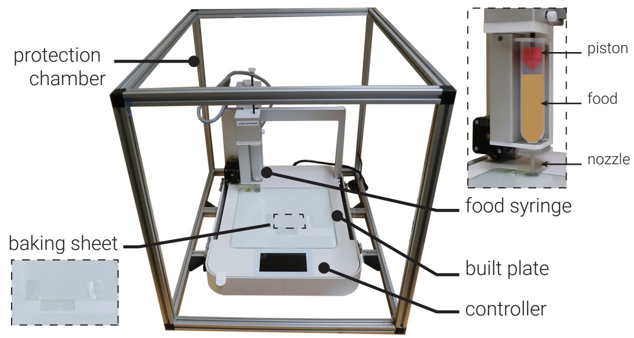

Figure 2: Food 3D Printer *3DbyFlow* used for fabricating the food structures. The baking sheet can be used to transfer the 3D printed food structure to an oven or pan. The protection chamber keeps the area clean and prevents airflow which may dry out the food while it is printing.

as input a user's selection from a list of foods, a level of hunger, and the remaining calories for the day (e.g., from a user's fitness tracker). The system then outputs a set of 3D printing parameters and a 3D printable .gcode file that creates the a food structure of the desired chewing time.

3D Printing Hardware and 3D Printed Food

All food structures printed were fabricated on the food 3D printer called *3DbyFlow* that is shown in Figure 2. The *3DbyFlow* printer allows accurate printing and fabrication of food with different internal structures, necessary to deploy different infill patterns and densities. Based on our experience with the 3D printer, food structures printed from the same 3D model (i.e., printed from the same ingredient amount) have an error rate of $\pm$0.10g, which we determined by weighting the 3D printed food structure using a standard weight scale (SHIMADZU ELB300).

Using the *3DbyFlow* printer, we tested different ingredients

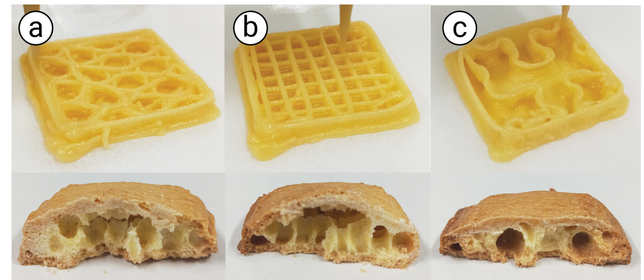

Figure 4: Varying Infill Pattern: (a) Honeycomb infill, (b) Rectilinear infill, and (c) Hilbert infill.

for creating 3D printed food structures. Since our work relies on internal structures of a specific pattern and density, we found that ingredients with the following properties work best for our approach: (1) form a sturdy structure at room temperature, (2) if post-processing (cooking, baking) is required, the food keeps the same shape, size, and internal structure.

Applications and Demonstration

To showcase the possibilities of FoodFab, we illustrate a range of different application scenarios:

Integration with Daily Meal Preparation: Food 3D printers that emerge on the consumer market tend to offer a list of recipes linked on the manufacturer website where a user can buy the ingredients as prefilled food capsules in supermarkets. FoodFab can be integrated into this emerging ecosystem around food 3D printers by using the computational models to personalize the recipes offered to consumers to help them manage their food intake.

Decreasing Food Size Over Time: People who overeat often have an attraction to large portion sizes to which they get accustomed over time [3]. Thus, to a person that overeats, a regularly sized meal may seem small in comparison. A future avenue for FoodFab would be to investigate if small changes in meal size over time can get users accustomed to regularly sized portions. We will demonstrate that we can modify the size of a piece of food by changing the infill density while keeping calories constant.

In our demonstration, we will shows our food 3D printer and the fabricated “cookie” with various infill parameters similar to the one used in the experiments (Figure 4 and Figure 3). We will also demonstrate our user interface that integrates the computational models with food 3D printing.

Conclusion

We demonstrated how to use personal fabrication devices to create food perceptual illusion. Rather than *digitally* augmenting food, we showed how to use food 3D printing to *physically* integrate perceptual illusions. For more details regarding the user studies and computational models, please refer to [1].

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