User Perceptions of 3D Food Printing Technologies

Tom Gayler
Lancaster University
Lancaster, LA1 4YW, UK
t.gayler@lancaster.ac.uk

Corina Sas
Lancaster University
Lancaster, LA1 4YW, UK
c.sas@lancaster.ac.uk

Vaiva Kalnikaitė
Dovetailed Ltd.
Cambridge, CB2 1NW, UK
vaiva@dovetailed.io

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Abstract
3D food printing technologies offer a range of opportunities for HCI, yet so far applications have been limited. We report a survey exploring the attitudes of early adopters towards 3D food printing technology, with the aim of helping designers create successful applications for this technology.

Author Keywords
3D printing food technologies; user perceptions; technology adoption.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
3D Food Printing (3DFP) is an emerging technology that offers a range of opportunities for designing novel user experiences. As with traditional 3D printing, it allows users to recreate digital models in physical form. The difference being, the materials and processes used are food-safe, meaning the output to be eaten by its creators. Food affords for multisensory experience and is deeply embedded in various social rituals in everyday life. Being able to leverage this connection provides interaction designers the opportunity to explore an emerging design space for user experience. As 3DFP

technology finds new applications it requires consideration as to how its users perceive it. The relationship the user has with the technology has potential to impact 3DFP's adoption as well as its future applications. The main contributions of this paper include the perceptions of 3DFP among different early adopter groups, and the perceived challenges and opportunities of 3DFP technologies.

Literature Review

We draw from HCI models of trust and technology adoption to approach the implications for 3DFP technology. Rogers [10] describes the characteristics of various user groups in relation to technology adoption. He identifies 'Early Adopters' as motivated by novel and rewarding experience and less concerned with the risks of technology in comparison to other population segments. The influence of risk and benefits on users has been explored through the Technology Adoption Model [11]. This model proposes 'Perceived Ease of Use' and 'Perceived Usefulness' as key factors influencing adoption. Ease of use is constructed from sources relating to the trust in, and experience of, technology. These factors are balanced, receiving different weights from differing populations. From the perspective of food technologies, both risks [1] and trust [3] are reported as influencing consumer acceptance of a foodstuff.

The interplay of the above factors has been applied to autonomous vehicles [9], with findings showing that positive user experiences best support adoption. The challenge of understanding the risks and benefits of 3DFP technologies lies in the lack of concrete applications. In order to create 3DFP technologies that are successfully adopted, it is important to understand perceived risks and envisaged contexts of use, in particular amongst early adopters who shape wider consumer perception [10].

Sample	N	Mean	SD	z-test	Sig. (p)
Cox & Evans Population [2]	294	55.00	11.90	--	--
3DFP Mailing List [4]	24	41.54	12.00	-5.54	<0.01*
3D Printing Forums	6	40.83	10.36	-2.92	<0.01*
Computer Science Students	20	48.15	8.31	-2.57	<0.01*

Table 1: Food Technology Neophobia Scores of survey groups and scale validation population. Significant difference is reported for each study group in comparison to population from [2].

The potential of 3DFP within HCI has received limited attention [5]; a noticeable exception being the EdiPulse system that prints chocolate rewards for physical activity [6]. With respect to the perception of 3DFP technology, we previously reported a preliminary analysis of survey data from 24 members of a 3DFP mailing list, with findings showing the experimental quality of such technologies and people's knowledge of sugary and fatty foodstuff [4]. The current paper extends this prior work in two ways by reporting data from 50 survey participants from two additional communities, and a richer data analysis.

Method

The research method consists of a survey exploring early adopters' perception, attitudes and knowledge of 3DFP technologies through three sections.

Sample	Adherence to Technology			Adherence to Natural Food			Enjoyment			Necessity			Suspicion		
	M	SD	z-test	M	SD	z-test	M	SD	z-test	M	SD	z-test	M	SD	z-test
Onwezen & Bartels [7]	3.11	0.80	--	3.75	0.88	--	3.70	0.84	--	2.20	0.87	--	3.01	0.73	--
3DFP Mailing List	5.21	0.87	12.86*	5.25	1.25	8.35*	6.22	0.77	14.70*	2.57	1.06	2.08	3.87	0.90	5.57*
3D Printing Forum	5.17	0.87	6.31*	3.67	1.61	3.95*	5.50	0.84	5.25*	3.00	0.87	2.25	3.67	1.48	2.21
Computer Science Students	4.77	0.85	9.28*	4.40	1.65	5.18*	5.70	1.42	10.65*	3.27	1.47	5.50*	3.90	0.95	5.45*

Table 2 : This table reports the scores for the three groups on the Social Representation Scale in comparison to the population scores from the validation study. Z-tests where $p<0.01$ are marked with a *

Figure 1 : 3D printed strawberry and cream berry. This demonstrates how foodstuffs can be reimagined through 3DFP technology. Photo courtesy of Dovetailed Ltd.

First, we used two valid and reliable scales, i.e. Food Technology Neophobia Scale (FTNS) [2], and Social Representations scale for novel foods [7] developed by food science researchers for measuring consumers' perception of novel foodstuffs. Second, we asked participants to report their perceived risks for sourcing, processing, selling, preparing and eating 3D-printed food. Third, we also asked about direct experiences of 3D food printing and the envisaged contexts where participants expected to see this technology used in.

Participants

The survey was targeted to three communities of potential early adopters' and answered by 24 members of Nufood's 3DFP Mailing List [4], 6 members of a 3D Printing Forum (www.3dprintboard.com), both groups were selected because of their familiarity with 3D printing, and 20 Computer Science students included to explore attitudes beyond those engaged with the 3D printing community. This study explores how well these groups do in fact represent early adopters.

Results

We now report the survey findings focusing on the attitudes, perceived risks and envisaged contexts of use of 3D printing technologies, alongside a comparison across the three groups.

Attitudes toward 3D Food Printing Technologies

Table 1 and 2 show the Mean and Standard Deviation for each of the three groups on the two scales, alongside the population score used for validating the scales [2,7]. Z tests were used to compare our samples against population means (taken from the scale validation studies), the results indicate that all groups are less neophobic towards food technology than the population [2]; 3DFP Mailing List (z=-5.54, p<0.01); 3D Printing Forum (z=-2.92, p<0.01); Computer Science students (z=-2.57, p<0.01). Z tests for Social Representation scale presented in Table 2 also indicate that all three groups show significantly higher adherence to technology than the validating population [7]; 3DFP Mailing List (z=-12.86, p<0.01); 3D Printing Forum (z=6.31, p<0.01); Computer Science students

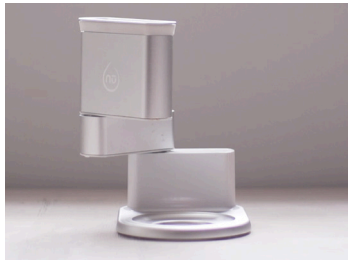

Figure 2: Nufood printer. This is designed to fit on a tabletop allowing for 3DFP to take place beyond industrial and lab contexts. Photo courtesy of

(z=9.28, p<0.01). A comparison of these scales' scores shows significant differences on the enjoyment dimension; 3DFP Mailing List (z=14.70, p<0.01); 3D printing forum (z=5.25, p<0.01); Computer Science students (z=10.65, p<0.01). This suggests that exposure or interest in 3DFP may offer a more engaging experience as opposed to 3D printing in general. Together these findings indicate that all three groups are significantly more open towards engaging with 3DFP technologies - a marker of early adopters [10].

Perceived Risks of 3D Food Printing

Food technologies bring new considerations for consumers deciding to try novel foodstuffs [2]. To better understand how the risks associated with 3DFP differ from other food technologies we prompted participants to describe perceived risks at five stages of food production (sourcing raw materials, processing materials into products, selling products, preparing products for consumption and eating the product). Findings indicate that perceived risks of sourcing 3D printed food is centered on environmental concerns, in line with the environmental impact of production for other food technologies (n=9): "*will [it] require the same land as non-printed food? No environmental benefit would make this more of a fad*" [Participant 18, Student]. When asked to consider the processing of this food, the major risks were adulteration and additives included in the final food product: *"I imagine a number of non-nutritional preservatives will possibly have to be added to the food"* [P12, Student]. In contrast to product-focused risks for the sourcing and processing, the perceived risk for selling related to consumers' lack of awareness and bias against this technology: *"consumer bias against trying new things and the stigma of 'artificial' food"* [P8, Student].

Perceived risks related to the preparation are where the most prominent divergence from traditional foodstuffs occurs. The major issue was the misuse or malfunction of the printer (n=20). Unlike most other food technologies (GM, Mass Production) the technology of 3D printed food is located much closer to the consumer. The potential for more creative use of the foodstuff is placed in the hands of the consumer but it also shifts the risk of malfunction closer to the consumer as well. The most prominent eating risk related to health and diet (n=14) however it was more nuanced with a focus on *"long term negative effects [that] are unknown, and untestable*." [P7, Student]. This uncertainty suggests a challenge in moving 3D food printing technology from a one-off experience into a tool for every-day use in domestic contexts.

While the risks we report at each stage echo the commonly perceived risks for all food technologies [1] they also focus on technology's common myths. In the selling of food, the major concerns relate to its opacity, limiting people's ability to understand how it works. There is no existing mental model for making sense of this technology which if not addressed, could hinder adoption.

Envisaged Uses of 3D Food Printing

The most commonly known 3D-printed foodstuffs are predominantly sweet tasting, with chocolate being the most used [6]. When asked if they had actually tried 3D printed food (3DFP Mailing list n=10, 3D Printing Forum n=1, Computer Science Students n=1) they reported trying it at exhibitions or dining events. In line

with this being an emerging technology it is expected to be seen at exhibitions, but its use in dining events suggests the technology may first mature as a tool whose primary purpose is provision of experience, rather than the provision of nourishment.

When asked about the envisaged uses for 3DFP technology most participants mentioned research (n=22). This suggests a non-domestic application and as of yet undefined role for 3DFP. The second most envisaged use was for creative purposes (n=21), here the ability of 3DFP to create *"novel shapes for confectionary"* [P18, Mailing List] was understood to offer potential for application in decoration and presentation of food. A more surprising use for the technology was in the provision of food aid in emergency situations (n=7). None of the participants provided reasons for this, although it is possible the technology is perceived as being able to construct satisfying meals from limited resources, we can see some evidence for this claim in Participant 19's [Student] suggestion to use the technology to *"convert rotten food to edible foods"*. A perhaps more feasible expectation for 3DFP is in assisting healthcare and healthy eating (n=6). Expectations ranged from portion control (recognizing the influence of digital control) to preparation of personalized diets (recognizing the model of micro-manufacture offered by 3D printing).

We also prompted speculative responses from our participants to imagine more unusual applications for 3DFP. Personalization (n=6) was the most often mentioned context, suggesting consumers' desire to tailor meals or dining experiences to their tastes. This also prompted responses that looked beyond the dinner plate with edible packaging [P15, Student], edible tattoos [P11, Student] and even sex toys [P14, Mailing List].

Discussion

We now discuss the findings and articulate several sensitizing concepts opening novel design opportunities [8] for 3DPF technologies in HCI. Findings indicate that 3DFP technology is understood mostly as a non-domestic technology raising concerns over the long-term effects to health of the foodstuff produced. Our early adopters experience enjoyment from the food technology which as previously suggested [4] places the focus on creating contexts of use where user experience is prioritized. In their speculations participants reported personalization of meals, utilizing the technology to create bespoke foodstuffs in the home. This offers an exciting opportunity to engage users in the design of their own food experiences, parameters such as taste and form can be guided through digital tools and production handled by the printing technology. Meals offer a promising context where 3DFP could offer benefits to systems promoting social interactions or healthy eating.

It is clear that early adopters are inspired by 3DFP's potential to be used in emergency aid contexts. Whilst there remain questions over the usefulness of 3DFP to this end, exploration in this area will be welcomed and supported by early adopters. Our findings suggest that such a humanitarian or entertainment value should be added to 3DFP in order to drive awareness and familiarity with the technology. 3DFP robots allow the production of food to take place in front of user's eyes. There is an opportunity to consider how the movements and process of printing can be designed into rituals of 3D printed food consumption. Lack of user awareness

towards the technology is a key barrier to wider adoption beyond early adopters. The technology not only moves creative potential towards the user but also a burden to ensure safety. This provides an insight for the wider HCI community, such as healthcare interventions where technology is empowering users and at the same time passing a burden of responsibility onto the users. Nonetheless 3DFP is an exciting and engaging prospect for early adopters. Further work should look to create experiences that engage the senses and make use of the affordances of the technology. We have seen how 3DFP technology can offer a range of novel and engaging contexts of use but creating successful systems requires consideration of the challenges we have reported here.

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