ChewBit: Enhancing Haptic Feedback with an On-Face Pneumatic Interface for Realistic Food Texture in VR

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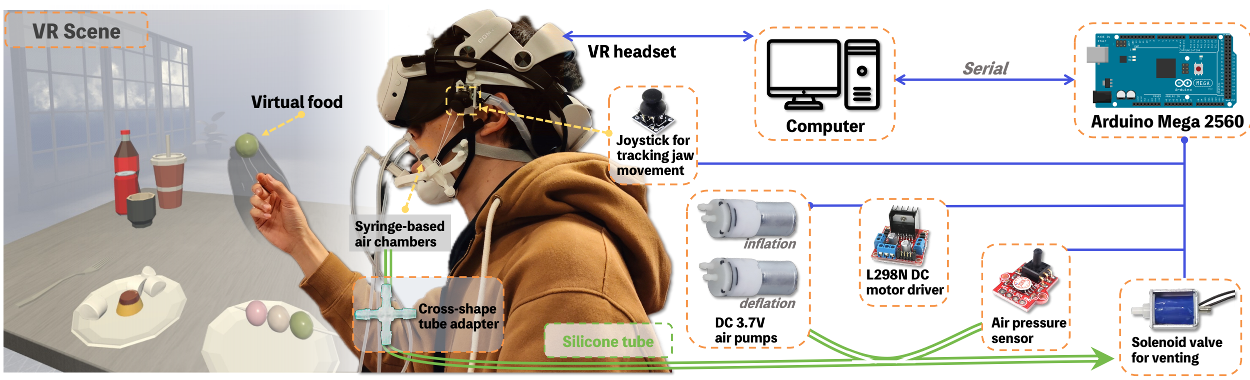

Figure 1: System diagram of *ChewBit*. *ChewBit* has two main parts: an on-face wearable module (with support frame, jaw-tracking joystick, air chambers, and jaw support) and a pneumatic actuation system (with air pumps, pressure sensor, solenoid valve, and Arduino controller).

CCS Concepts

• **Human-centered computing → Virtual reality**; **Haptic devices**.

Keywords

Virtual reality, Haptic devices, Food Texture

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1 Introduction

In recent years, researchers have explored a wide range of haptic devices to enhance multisensory experiences in virtual reality (VR). Among these experiences, food intake stands out as a fundamental multisensory daily activity. Simulating these stimuli can positively influence dietary behaviors, social interactions, and overall enjoyment in eating [Mueller et al. 2023].

Robotic food texture analysis has been used to study the simulation of chewing sensations [Shibata et al. 2019]. In addition, existing

Figure 2: (a) On-Face Wearable Module. (b) Jaw Movement Tracking. Difference VR Applications for (c) Social Eating, (d) Healthcare and Rehabilitation and (e) Food Experience Design

approaches have leveraged augmented reality overlays [Narumi et al. 2011], on-tongue electrical stimulation [Ranasinghe and Do 2016], and cross-modal techniques such as modified chewing sounds [Koizumi et al. 2011] to modulate perceived flavor or texture. However, replicating food's mechanical properties—particularly hardness, cohesiveness, and stickiness—remains challenging. Electrostimulation methods [Niijima and Ogawa 2016] and intra-oral mechanical linkages [Iwata et al. 2004] can provide force feedback but raise concerns regarding user comfort, hygiene, and reliability.

Pneumatic devices worn on the user's face offer a promising alternative, given the high tactile sensitivity of facial skin [Corniani and Saal 2020]. We propose *ChewBit* (see Fig. 1), a novel face-worn pneumatic haptic interface designed for realistic food texture simulation. *ChewBit* leverages syringe-based pneumatic actuators integrated into an ergonomic face frame to deliver modulated force feedback. The system tracks jaw movement via a dual-axis joystick module, allowing an Arduino-based controller to generate PWM signals that drive air pumps and solenoid valves. By controlling inflation, deflation, and air pressure, *ChewBit* can render food texture properties—such as hardness, cohesiveness, and stickiness—that are essential for an immersive eating experience.

2 System Description and Implementation

ChewBit is a face-worn pneumatic haptic interface designed to simulate various food textures in VR through on-face kinesthetic feedback. Fig.1 illustrates the system diagram of *ChewBit*, which integrates syringe-based actuators, a support frame, and real-time control architecture for immersive chewing experiences.

2.1 Simulating Food Texture with Pneumatics

Food texture perception arises from the integration of visual, auditory, and—most critically—kinesthetic cues gathered during mastication [Rosenthal and Chen 2024]. The tactile properties of food—namely hardness, cohesiveness, and stickiness—are determined by the mechanical interactions between food and the masticatory system (teeth, tongue, and jaw muscles) [Miller 2017]. Specifically, hardness is perceived as the force needed to deform or break food, cohesiveness reflects the spring-like resistance to deformation, and stickiness corresponds to the force required to overcome adhesion during food separation [Rosenthal and Chen 2024].

ChewBit provides chewing resistance through pneumatic actuation. By controlling inflation, deflation and venting timing, *ChewBit* modulates air pressure within syringe-based actuators to generate tailored force profiles: inflation produces compressive forces that simulate the resistance of cohesive and hard foods, while deflation creates tensile forces that mimic the sensation of stickiness.

2.2 Hardware

A 3D-printed wearable frame is designed to securely house the actuators while ensuring user comfort, as shown in Fig.2(a). *ChewBit* employs three syringe-based actuators, each converted from a 5 mL syringe barrel with plungers and pistons for uniform force delivery. YAMATE FL-935 lubricant reduces friction between piston and barrel. The air chambers are interconnected via a tube adapter, controlled by a solenoid valve, and attached to the user's jaw using articulated linkages allowing up to 45° swing. Internal pressure is regulated by inflate and deflate pumps (DC 3.7V micro air pump 370) when the chambers are sealed.

ChewBit's pneumatic system regulates sealed air chambers across a −55 kPa to +65 kPa pressure range. Each 13.3 mm diameter chamber provides forces from −7.66 N (jaw-opening) to +9.05 N (jaw-closing), based on $F = P \cdot A$. With three chambers, the total force output ranges from −22.98 N to +27.15 N.

To trigger the pneumatic control in real time, we installed a dual-axis joystick module (HW-504) on the side of the wearable support frame (shown in Fig.2(b)) to detect the phases of jaw opening and closing. The analog signal from the joystick could reflect the jaw movement with a short responsive time.

2.3 VR Integration

The VR application, developed in Unity for Meta Quest 3, communicates with *ChewBit*'s Arduino Mega 2560 board via serial signals. The joystick on the device monitored the user's chewing actions and was synchronized with a collision box in the VR environment representing the user's virtual jaw. In the VR scene, the user's hand motion was tracked to grab virtual food and perform a feeding motion to simulate placing the food into their mouth. When the VR program detected that the virtual jaw was about to "chew" the virtual food (via the collision box), the pneumatic system triggered the corresponding haptic feedback for chewing.

2.4 Potential Applications

We developed various food interaction experiences in VR using *ChewBit*, as shown in Fig.2(c)(d)(e). *ChewBit* has the potential to support remote social eating in VR, enabling shared tactile interactions and highlighting the emotional aspects of food experiences. Its robust force feedback also offers prospects for healthcare and rehabilitation, assisting individuals with limited chewing functions and supporting dietary management. Furthermore, the system's ability to incorporate multimodal cues (e.g., smell, taste, temperature) expands its potential for creating immersive, multisensory food experiences in VR.

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