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Effects of the sound of the bite on apple perceived crispness and hardness

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ABSTRACT

The effects of the manipulation of the sound produced while biting into apple samples, a non-dry food, was investigated. In Experiment 1, participants rated the perceived crispness of flesh cylinders obtained from three apple cultivars differing in their texture profile: 'Renetta' (white 'Renetta Canada'), 'Golden' ('Golden Delicious'), and 'Fuji'. Participants might hear the veridical sounds they made when biting into an apple cylinder without any frequency adjustment (0 dB filter) or with high frequencies attenuated (either by −12 dB or by −24 dB). Perceived crispness was significantly lower when any of the reductions were applied than when no filter (0 dB) was used. In Experiment 2, new participants rated both crispness and hardness of 'Renetta' and 'Fuji' cylinders. The sound of the bite could be unfiltered (0 dB), reduced in its high frequencies (−24 dB), or globally reduced (the microphone was switched off). Crispness, again, was perceived as significantly lower with any of the sound reductions. Interestingly, perceived hardness was significantly affected by the sound information as well: Hardness was rated as being significantly lower when a global sound reduction was applied than when the sound was unfiltered. We demonstrated, for the first time, that sound information plays an important role even for the evaluation of hardness, a property believed to be primarily oral/mechanical.

Introduction

Sensory quality is identified as the most important driver of consumers' choices when it comes to fruit product selection (Harker, Gunson, & Jaeger, 2003). This seems particularly true for apple, which preference has revealed to be primarily guided by the degree of freshness (Péneau, Hoehn, Roth, Escher, & Nuessli, 2006). Freshness evaluation in apple strongly relies on texture properties, among which crispness and hardness appear to play a chief role (Daillant-Spinnler, MacFie, Beyts, & Hedderley, 1996; Jaeger, Andani, Wakeling, & MacFie, 1998; Péneau, Brockhoff, Hoehn, Escher, & Nuessli, 2007; see also Péneau et al., 2006). Although the number of studies focusing on the description of crispness sensation is remarkable, still an unambiguous and universally agreed definition is missing. Crispness would refer to some sound characteristics of the noise produced by the apple when it is bitten with the front teeth (Harker et al., 2002), as well as to the vibrations produced by the apple when it breaks (Christensen & Vickers, 1981; Szczesniak, 1988), and to the strength needed to obtain such fracture (Seymour & Hamann, 1988). Hardness, instead, appears to be a more defined property as it is related to the resistance of the apple flesh when the biting action is exerted by the teeth (Daillant-Spinnler et al., 1996). Still, there are authors suggesting that hardness would also share some properties with crispness (see Fillion & Kilcast, 2002; Vincent, 1998).

The role of sound in judgments of food texture was first investigated by Drake (1963, 1965). Drake demonstrated that the sounds produced by chewing or crushing a variety of foodstuffs (or the same foodstuff prepared to have different textures) varied in their amplitude, frequency, and temporal characteristics. In following years, Vickers and collaborators went onto investigating the role of sound on the perception of some textural characteristics of food like crispness and crunchiness (for an early review, see Vickers & Bourne, 1976a). Initially, the crucial role played by sound

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was unveiled, observing for instance that foods differing in their crispness level also significantly differed in their produced noise pattern when they were crushed (Vickers & Bourne, 1976b; for instrumental data, see Zdunek, Konopacka, & Jesionkowska, 2010). In subsequent studies, Vickers and colleagues proposed that the nature of crispness could be more complex. According to them, this property would not only be evaluated by measuring some sound characteristics during food crushing (Vickers & Bourne, 1976a), but would also be related to the tactile sensations produced by the vibrations generated during the action of biting into the food (Christensen & Vickers, 1981). As a matter of fact, Vickers and Bourne found evidences that food crispness could be correctly estimated even when the sound generated by the bite and the chew was masked.

As for hardness, it is a textural parameter considered as being predominantly mechanical in nature (Brown, Langley, & Braxton, 1998) as it is defined as the maximum force necessary for the jaws or an instrumental probe to break the food product (Vincent, 1998). Nevertheless, there are some empirical data that suggest a possible connection to sound information: Volunteers exposed to the pre-recorded sound of different foods crushed by hand were able to extract some kind of information about food hardness from the acoustic cues (Vickers & Wasserman, 1980). There are also instrumental demonstrations that include the possibility to predict to a certain extent hardness from acoustic data generated using an acoustic emission detector (Zdunek, Cybulska, Konopacka, & Rutkowski, 2010). In addition to this, the existence of a correlation between crispness and hardness evaluations has been repeatedly reported in the literature (e.g., Brown et al., 1998; Corollaro et al., 2013). However, studies definitively understanding the role of sound in hardness perception do not exist and should be investigated.

Previous research has focused mainly on the type of information that could be derived from the sound (either recorded or in real-time) during biting and crushing of foods. However, Zampini and Spence (2004) adopted a multisensory approach for studying the role auditory cues play in food perception. These researchers investigated the possible auditory modulation of tactile, mechanical, and kinaesthetic information on food perception and evaluation by simply changing the sound the person could hear when biting into commercial potato chips (Zampini & Spence, 2004). In particular, crispness and freshness, two properties that are strongly related to food quality, were judged. These authors demonstrated that a real-time increase or decrease of specific audio frequencies resulted in a symmetrical increase or decrease of the perceived crispness and freshness of the product. These results confirmed the ability of sound feedback to significantly influence a consumer's experience.

Zampini and Spence (2004) proved the existence of a close link between sound and specific sensory properties in dry foods, which are products strongly characterised by their level of crispness. For high moisture foods, Fillion and Kilcast (2002) investigated the perceived crispness and crunchiness in fruit and vegetable products. These authors highlighted the importance of crispness in the evaluation of high moisture food using both consumers and trained panelists. Later, Masuda, Yamaguchi, Arai, and Okajima (2008) have also described the influence of the sound produced during chewing on the perception of food moisture, thus confirming the important linkage between sound and sensory properties of foods.

The process of food evaluation focusing on the sound produced during consumption is a very complex mechanism that relies on more than one transmission path. During biting, a large amount of the acoustic information travels through the air reaching the ear of the perceiver (i.e., air-conduction mechanism). The remaining amount of sound reaches the ear from the inside through its transmission from the teeth, jaws, and bones (i.e., bone-conduction mechanism; see Vickers & Bourne, 1976b). While the jaws can act as a resonance system amplifying the frequencies of sound around 160 Hz, the soft tissues of the mouth (cheeks and tongue) dampen the high frequencies of the sound produced. Kapur (1971) recorded bone-conducted sounds during chewing at a site close to the source (i.e., the mandible near its angle) and at a distant site near the ear canal. It emerged that bone-conducted sounds that reach the ear canal are dramatically attenuated (of approximately 50%). Christensen and Vickers (1981) observed that the use of white noise to mask the air-borne sound produced by biting did not affect the discrimination of crispness of different foods, suggesting that sound may not be essential for this kind of judgments and that other sensory information should be taken into account (e.g., oral touch; Christensen & Vickers, 1981). More recently, Dacremont, Colas, and Sauvageot (1991) measured the relative contribution of air- and bone-conduction to the evaluation of food by biting and chewing. These authors observed that during biting both systems contributed to the sensation equally. When the food was chewed instead, air-borne information appeared to have a heavier weight on the global sensation, as bone-conducted sound was strongly dampened by the soft tissues.

This present study was inspired by Zampini and Spence's findings (2004) and therefore a similar procedure was applied but with some relevant differences. While Zampini and Spence asked the volunteers to evaluate sensory differences in the acoustic domain exclusively (as the potato chips were all of the same kind), in this study the volunteers were asked to judge apples intrinsically differing in terms of their sensory properties (i.e., crispness and hardness). This was done in order to avoid any possibility to prompt the participants to preferentially attend to one sensory dimension (i.e., auditory) over the others, thus biasing their perception (e.g., see Spence & Driver, 2004), and to try and take into account the variability of the sensory properties naturally present in fresh foods.

Additionally in the present study, the attention was directed to the investigation of any possible influences of air-borne sound on the perception of texture properties of a high moisture food, that is apple. Indeed, food with high moisture content behaves differently from dry foods under crushing conditions (Duizer, 2001), therefore different effects of sound might be observed. For this reason, we focused on the effects exerted by the manipulation of the acoustic information captured during the consumption of different apple varieties, based on the ratings of crispness, one of the most important driver for preference (Experiment 1). In the second test (Experiment 2), we go on to verify whether sound could be relevant also when evaluating hardness, a mainly mechanical property of food, given the inconsistent results in sensory studies literature.

Experiment 1

Method

Participants

Seventeen untrained participants (13 females and 4 males, mean age = 26 years old) took part in this study. There were no reported hearing problems from participants. All of the participants were naïve as to the purpose of the experiment and an informed consent was signed before starting the experimental session.

Stimuli

Three apple varieties were used as stimuli: 'Renetta' (white 'Renetta Canada'), 'Golden' ('Golden Delicious'), and 'Fuji'. These varieties were selected on the basis of an extensive characterisation by descriptive sensory analysis (Corollaro et al., 2013) that classified these apples as differing in terms of the textural