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Cross-modal influence on oral size perception

Parker Crutchfield[a,*], Connor Mahoney[a], Vanessa Pazdernik[b], Cesar Rivera[a]

[a] Missouri School of Dentistry and Oral Health, A.T. Still University, 800 West Jefferson St., Kirksville, Missouri 63501, USA
[b] Research Support, A.T. Still University, 5835 E. Still Circle Dr., Mesa, Arizona 85206, USA

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ABSTRACT

Objective: Evidence suggests people experience an oral size illusion and commonly perceive oral size inaccurately; however, the nature of the illusion remains unclear. The objectives of the present study were to confirm the presence of an oral size illusion, determine the magnitude (amount) and direction (underestimation or overestimation) of the illusion, and determine whether immediately prior cross-modal perceptual experiences affected the magnitude and direction.
Design: Participants ($N = 27$) orally assessed 9 sizes of stainless steel spheres (1/16 in to 1/2 in) categorized as small, medium, or big, and matched them with digital and visual reference sets. Each participant completed 20 matching tasks in 3 assessments. For control assessments, 6 oral spheres were matched with reference sets of same-sized spheres. For primer-control assessments, similar to control, 6 matching tasks were preceded by cross-modal experiences of the same-sized sphere. For experimental assessments, 8 matching tasks were preceded by a cross-modal experience of a differently sized sphere.
Results: For control assessments, small and medium spheres were consistently underestimated, and big spheres were consistently overestimated. For experimental assessments, magnitude and direction of the oral size illusion varied according to the size of the sphere used in the cross-modal experience.
Conclusion: Results seemed to confirm an oral size illusion, but direction of the illusion depended on the size of the object. Immediately prior cross-modal experiences influenced magnitude and direction of the illusion, suggesting that aspects of oral perceptual experience are dependent upon factors outside of oral perceptual anatomy and the properties of the oral stimulus.

1. Introduction

The ability to perceive the size of objects in the oral cavity is necessary for successful performance of a range of activities, such as chewing and swallowing, and determining the clinical outcomes of some dental treatments, such as prosthodontic treatments. However, with the exception of taste perception, oral perception has been infrequently researched, and comparatively little is known about the perceptual capacity.

Although the presence of an oral size illusion is acknowledged and oral perception of size is commonly inaccurate, research that actually establishes the presence of the oral size illusion is equivocal. Evidence indicates that the size of holes in the oral cavity, as explored with the tongue, are consistently overestimated (Anstis, 1964; Anstis & Loizos, 1967; La Pointe, Williams, & Hepler, 1973). In these studies (Anstis, 1964; Anstis & Loizos, 1967; La Pointe et al., 1973), participants matched the size of the holes with digital or visual reference sets. In some cases, the overestimation of size was greater for the smaller holes (Anstis, 1964; Anstis & Loizos, 1967), and in others it was greater for the larger holes. In contrast, one study (La Pointe et al., 1973) found a slight underestimation for the smaller holes.

This consistent overestimation in oral size perception is further supported by Dellow, Lund, Babcock, and van Rosendaal (1970). In that study (Dellow et al., 1970), participants assessed the size of intra-oral cylinders. When cylinders were presented intra-orally, most of the errors were an overestimation (Dellow et al., 1970). In more recent studies (Bittern & Orchardson, 2000; Melvin & Orchardson, 2001), participants assessed the size of small holes and pegs embedded in an inter-oral device with their tongues and fingers. For oral perception of both holes and pegs, participants overestimated the size. However, for a minority of the small and large sizes, participants tended to underestimate the sizes of the pegs (Bittern & Orchardson, 2000; Melvin & Orchardson, 2001). In contrast, La Pointe et al. (1973) showed that when visually and digitally matching the size of holes assessed with the tongue, visual assessment was more accurate than digital assessment. In a study by Engelen, Prinz, and Bosman (2002), participants assessed

* Corresponding author.
E-mail addresses: pcrutchfield@atsu.edu (P. Crutchfield), cmahoney@atsu.edu (C. Mahoney), vpazdernik@atsu.edu (V. Pazdernik), crivera@atsu.edu (C. Rivera).

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the size of steel spheres inside the mouth with and without a customized plastic covering of the palate. Regardless of palate covering, participants visually underestimated the size of the smaller spheres and overestimated the sizes of the larger spheres. In some cases, the oral size illusion was diminished when participants wore the palate covering (Engelen et al., 2002). Engelen et al. (2002) used visual matching of spheres and found underestimation of oral size. Topolinski and Türk Pereira (2012), in a recent study, used digital matching of round straws and also found underestimation.

Results of these previous studies (Anstis, 1964; Anstis & Loizos, 1967; Bittern & Orchardson, 2000; Dellow et al., 1970; Engelen et al., 2002; La Pointe et al., 1973; Melvin & Orchardson, 2001; Topolinski & Türk Pereira, 2012) are inconclusive because no clear understanding of this phenomenon can be determined: oral size perception appears to be underestimated or overestimated depending on the size and shape of the object and regardless of whether the reference matching task is visual or digital. Further, perceptual experience varies depending on an individual's environment, such as properties of the surrounding environment (Adams, Graf, & Ernst, 2004); memories, expectations, or biases (Churchland, 1988; Fisher, Hull, & Holtz, 1956; Hansen, Olkkonen, Walter, & Gegenfurtner, 2006; Pylyshyn, 1999); sociolinguistic environment (Winawer et al., 2007); or other immediately prior perceptual experiences (Pylyshyn, 1999). It seems likely that oral perception is not exempt from these influences. Therefore, the objectives of the present study were to confirm the presence of an oral size illusion, determine the magnitude (amount) and direction (underestimation or overestimation) of the illusion, and determine whether immediately prior cross-modal perceptual experiences affected the magnitude and direction.

2. Materials and methods

Participants were recruited by e-mail and excluded if they were unhealthy, had a history of choking, or had current orthodontic or prosthodontic dental treatment that would have interfered with oral size perception. The present study was approved by the local institutional review board (redacted for blind review), and all participants signed approved informed consent forms prior to participating.

In the present study, participants were tasked with assessing the size of stainless steel spheres in the oral cavity. Nine sizes of spheres were used in the assessments; they ranged in size from 1/16 inch to 1/2 inch and each sphere size was assigned a specific number (Table 1). To minimize the influence that perceptual memory may have had on size assessments from previously assessed spheres, the sphere sizes used across all assessments were not uniform. Additionally, the largest and smallest sphere sizes were not used as oral spheres during assessments, so that participants always had the opportunity to overestimate or underestimate the size of the sphere being assessed. Spheres were grouped into 3 general size categories (small, medium, or big) (Table 1). Oral size assessments were matched with a digital or visual reference set. Both visual as well as digital reference sets, rather than one or the other, were used, because previous research suggests that the oral size illusion manifests by way of both perceptual modalities. Both reference sets consisted of one of each size of sphere attached to a transparent acrylic display stand. Participants completed 20 oral size assessments (matching tasks) that were divided into 3 categories of assessments: control, primer-control, and experimental (Table 2). One sphere (#6) was never assessed, but was included in the reference sets so that there was visual and digital continuity among the spheres in the reference set, allowing the participants to make more fine-grained size assessments. All assessments occurred in the same temperature-controlled room under normal lighting conditions.

There were 6 control assessments: 3 oral–visual assessments (O–V) and 3 oral–digital assessments (O–D). For the O–V assessments, participants were blindfolded and given a cup containing a small, medium, or big sphere. Participants were instructed to place the sphere in their mouth. There were no restrictions on how participants could orally assess the size of the sphere. Participants then removed the blindfold and, with the sphere still in the mouth, matched the sphere with a visual reference set. The selection was recorded by a study investigator. Procedures for the 3 O–D assessments were the same, except participants kept the blindfold on and matched the oral sphere with a digital reference set.

Primer-control assessments were similar to control assessments, where the participant matched an oral sphere with a digital or visual reference set. However, for these assessments, participants made a digital or visual assessment of a sphere (priming sphere) that was the exact same size as the oral sphere immediately prior to the oral assessment. Participants completed 6 primer-control assessments: 3 digital–oral–visual (D–O–V) assessments and 3 visual–oral–digital assessments (V–O–D). For D–O–V assessments, participants were blindfolded and given a priming sphere in a cup. They poured the sphere from the cup into their hands and then while blindfolded digitally assessed its size. After returning the priming sphere to the cup and the cup to study investigators, participants were given a cup containing an oral sphere of the same size; they assessed oral size using the same procedure for control assessments. After completing the oral size assessment, they matched the size of the oral sphere with a visual reference set, using the same procedure as that of the control assessments. For V–O–D assessments, the procedures were the same, except participants visually assessed the size of the priming sphere and matched the size of the oral sphere with a digital reference set.

Experimental assessments were similar to primer-control assessments, where participants made a digital or visual assessment of a sphere (priming sphere) immediately prior to the oral assessment. However, for these assessments, the size of the priming sphere and oral sphere were different sphere sizes (small, medium, big). Participants completed 8 experimental assessments: 4 D–O–V and 4 V–O–D. Procedures for these assessments

Table 1
Sizes and size categories of stainless steel spheres used in the present study.

Sphere size (in)	Converted sphere size (mm)	Sphere identifier number	Sphere size category
1/16	1.6	1	Small
1/8	3.2	2	Small
3/16	4.8	3	Small
7/32	5.5	4	Medium
1/4	6.35	5	Medium
5/16	7.9	6	Medium
3/8	9.5	7	Big
7/16	11.1	8	Big
1/2	12.7	9	Big