The Relationship between Oral Stereognosis and Functional Measures of Swallowing

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Abstract

Objectives: Sensation is necessary for safe and efficient swallowing. There are currently few techniques used for the assessment and improvement of oral sensory function. Oral stereognosis (OS) has been proposed as an assessment of oral sensation. OS is the ability to recognise and discriminate shapes in the oral cavity. The first objective of this study was to explore the impact of stimulus size on oral stereognostic ability (OSA). The second objective was to determine whether any significant correlations exist between OSA and functional assessments of swallowing.

Methods: Fifty healthy participants, with no swallowing difficulties, aged 55 years and older were recruited. Participants completed an assessment of OS, the Test of Mastication and Swallowing Solids (TOMASS) and the Timed Water Swallowing Test (TWST). Participants were required to identify twenty different shapes in their mouths in three sizes. A one-way MANOVA was used to determine the effect of stimulus size on OSA. Pearson's correlation coefficient determined the relationship between OSA and measures from the TOMASS and TWST.

Results: Larger shapes had a higher identification score and shorter response time than smaller shapes. Significant correlations were found between OS score and response time and measures of the TOMASS and TWST

Conclusion: Several conclusions from this study can be drawn. Firstly, stiumulus size effects OSA in healthy adults. Secondly, OSA is significantly correlated to several measures from the TOMASS and TWST. This may suggest that OSA may be indicative of oral phase efficiency in swallowing.

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List of Abbreviations

OS	Oral Stereognosis
OSA	Oral Stereognostic Ability
TIA	Transient Ischaemic Attack
TOMASS	Test of Mastication and Swallowing Solids
TWST	Timed Water Swallow Test
fMRI	Functional Magnetic Resonance Imaging

Chapter 1: Introduction

Swallowing is important for eating and drinking. Sensory and motor function are necessary for safe and efficient swallowing (Chamberlain et al., 2007; Kumamoto, Kaiba, Imamura, & Minakuchi, 2010). Impaired swallowing impacts the health and quality of life of patients. As such, it is important that Speech Language Therapists can accurately assess, manage and rehabilitate the motor and sensory components of swallowing impairments. Limited research currently exists on the exact role of oral sensation in swallowing.

Stereognosis is the ability to discriminate shapes through touch in the absence of visual and auditory input (Jacobs, Serhal, & van Steenberghe, 1998). In the oral cavity, this is referred to as oral stereognosis (OS). OS is the process where sensory information about a bolus, or other stimulus, is perceived by sensory receptors located in the oral cavity (Fujii et al., 2011; Park, 2017). For oral stereognosis, a stimulus is placed within the oral cavity and the lips, teeth, tongue and palate are used to identify its shape (Ahmed, Hussain, & Yazdanie, 2006; Park, 2017). It is thought that OS could be used to assess oral sensory function. There is currently limited research available on the effect of stimulus size on a person oral stereognostic ability (OSA).

Clinicians use swallowing assessments to evaluate a person's swallowing ability. There are currently limited assessments available to assess oral sensation (Park, 2017). The TOMASS is a clinically used swallowing assessment that evaluates oral phase efficiency of solid bolus ingestion of a cracker. The TWST is another clinically used assessment of swallowing which evaluates swallowing efficiency with a liquid bolus. No research is currently available on whether any correlations exist between OS and functional assessments of swallowing.

This study will increase the current understand of the relationship between oral sensation and swallowing in healthy adults over the age of 55 years with no swallowing difficulties. This study will explore the effect of stimulus size on participants OSA. This study will also explore whether any significant correlations exist between OSA and the clinically used assessments of swallowing, the TOMASS and TWST.

Chapter 2 discusses the current literature available regarding oral sensation and swallowing. The methods used in this study are described in chapter 3. In chapter 4, the results of this study are presented. Finally a discussion of the study, its results and conclusions are explained in chapter 5.

Chapter 2: Literature Review

2.1 Swallowing

Swallowing is the complex process of transporting food and fluid from the mouth to the stomach (Hennessy & Goldenberg, 2016). It involes 31 paired striated muscles and six cranial nerves (Dodds, Stewart, & Logemann, 1990). Swallowing is a sensory and motor process. Sensation aids in the planning, co-ordination and execution of the swallowing process (Humbert et al., 2009a). Precise co-ordination between the respiration and swallowing functions is necessary for the body to safely recieve nutrition and to avoid food and/or fluid entering the airway (Walton & Silva, 2018).

2.1.1 Phases of Swallowing

Swallowing can divided and conceptualized in four phases; however, it is one continous process. The phases of swallowing are the pre-oral (anticipatory) phase, the oral phase, the pharyngeal phase and the esophageal phase (Daniels, Huckabee, & Gozdzikowska, 2019).

2.1.2 Pre-oral Phase

Leopold and Kagel (1997) present the idea that the swallowing process begins before the bolus enters the oral cavity. The pre-oral phase is the interaction of pre-oral motor, cognitive, pyschosocial and somataesthetic elements which begin the swallowing process. The sensory information of a bolus, in part from the optic and olfactory cranial nerves, is processed in the cortex to begin to develop a swallowing plan.

2.1.3 Oral Phase

The oral phase begins when food or fluid enters the oral cavity (Daniels et al., 2019). The oral phase can be divided into two parts, the first part is oral preparation where the bolus is manipulated and formed within the oral cavity (Walton & Silva, 2018). On entering the oral cavity the lips close anteriorly and the tongue forms a seal against the velum to prevent bolus loss while the bolus is being prepared. The bolus is then formed through the coordination of lips, jaw movement, cheeks and tongue movement. Oral preparation finishes when the bolus is sufficiently prepared for safe swallowing (Daniels et al., 2019). The second part of the oral phase is the oral transfer. Once the bolus is formed, it is positioned on the tongue against the hard palate and propelled posteriorly (Hennessy & Goldenberg, 2016; Walton & Silva, 2018)

2.1.4 Pharyngeal Phase

The pharyngeal phase of swallowing refers to the bolus movement through the pharynx and the protection of the airway (Lang, 2009). It begins with the elicitation of the pharyngeal swallow as the bolus is transferred from the oral cavity and into the pharynx (Daniels et al., 2019). As described by Daniels et al. (2019), Hennessy and Goldenberg (2016) and Walton and Silva (2018) a series of rapid, sequential events occur during the pharyngeal swallow. The solft palate elevates to seal off the nasopharynx, laryngeal closure occurs through the closure of the true vocal folds, false vocal folds, arytenoids, aryepiglottic folds and epiglottis. The superior and anterior movement of the hyoid and larynx is achieved through contraction of the suprahyoid muscles and thyrohyoid muscle. The upper esophageal sphincter is opened by a combination of relaxation of the cricopharyngeus muscle and anterior hyolaryngeal movement. Finally dynamic pressure is used to move thre bolus through the pharynx through the base of tongue contraction to the posterior pharyngeal wall.

2.1.5 Esophageal Phase

The esophageal phase begins as soon as the bolus passes through the upper esophageal sphincter. Perisaltic waves push the bolus through the lower esophageal sphincter, which relaxes, and into the stomach (Lang, 2009; Walton & Silva, 2018).

2.1.6 Swallowing and Sensation

The phases of swallowing and the motor movements have been discussed but not the role of sensation during the swallowing process. Sensory input is necessary for all phases of swallowing and aids in the planning and execution of the swallowing process (Hirano, Hirano, & Hayakawa, 2004; Lowell et al., 2008; Steele & Miller, 2010). Bolus characteristics are perceived by oral sensory receptors, this sensory information is then relayed to higher cortical regions to support the planning and execution of bolus mastication, manipulation and the initiation of swallowing (Hirano et al., 2004; Steele, Hill, Stokely, & Peladeau-Pigeon, 2014; Steele & Miller, 2010). During the oral phase of swallowing, sensory feedback for the palate, teeth, mucosa of the mouth, gums and anterior two thirds of the tongue are provided by the trigeminal nerve (Daniels et al., 2019). The glossopharyngeal nerve provides sensory information for the soft palate, pharyngeal wall, faucial arches and posterior one third of the tongue (Daniels et al., 2019). This tactile sensory input is paired with taste sensory input through the facial and glossopharyngeal nerves and is transferred to the nucleus tractus solitarius, which then uses this information to modify motor planning of the pharyngeal swallowing event (Daniels et al., 2019). Sensory information enters the brainstem via the nucleus tractus solitarius. This sensory information is processed and integrated into the swallowing motor plan which is then transmitted to the motor nucleus to allow for execution of the pharyngeal swallow (Daniels et al., 2019). The interactive process between sensory and motor nuclei to create and modulate the motor plan allows for the safe swallowing of a variety of bolus sizes, temperatures and textures (Steele & Miller, 2010).

2.2 Oral Stereognosis

Most rehabilitation approaches for dysphagia focus on using motor strategies to improve motor function and co-ordination. There are currently few techniques for assessment and improvement of sensory function (Kawagishi, Kou, Yoshino, Tanaka, & Masumi, 2009; Park, 2017). One strategy for the assessment of oral sensation is oral OS. Stereognosis is the ability to recognise and distinguish between forms through touch in the absence of visual input (Jacobs et al., 1998). In the oral cavity, this is referred to as OS. OS evaluates both oral sensation and motor function. For this assessment, stimuli of various shapes are manipulated within the oral cavity and sensory receptors located in the oral mucosa, tongue, gums and lips are used to discriminate shapes in the absence of visual input (Ahmed et al., 2006; Park, 2017) Having a high OSA is presumed to represent intact oral sensation, as the individual has received sufficient sensory information to be able to accurately identify the shape (Ikebe et al., 2007).

Test pieces used in oral stereognosis impact the accuracy of the responses of the participants and the time needed to identify the stimuli (Shetty, Prasad, Rani, & Shetty, 2007). Jacobs et al. (1998) state that stimuli used in a test of OSA should consist of familiar patterns and have a variety of characteristics including straight lines, angles, curves and differences in length and width. A variety of shapes and differing number of stimuli can be seen throughout the literature. Weinburg (1967) developed a set of twenty shapes which they divided into six 'shape groups' including a polygonal group, triangular group, star group, circular group, convex group and a concave group. The rationale behind these shapes that there were a variety of different shapes with some similar and some more difficult to identify. Interestingly, studies which use more shapes, do not report participants accurately identifying all shapes (Kawagishi et al., 2009; Meenakshi, Gujjari, Thippeswamy, & Raghunath, 2014; Park, 2017). Compare this to Ikebe et al. (2007) who used six shapes, a circle, oval, square, rectangle, triangle and semi-circle in two different sizes who reported three of the 30 participants correctly identified all the shapes in both sizes. Fujii et al. (2011) compared the cerebral activation for manual and oral stereognosis. For this study, the shapes made were unidentifiable and a pilot study of 10 participants were unable to identify these shapes. The rationale was that for fMRI (functional magnetic resonance imaging) they needed cerebral activation for a certain length of time to ensure imaging of the cerebral activation. These studies demonstrate the variability in assessing OSA as some studies use shapes that can all be accurately identified to shapes which cannot be identified.

There is variability in scoring OS. Most studies report on an OS score, the number of stimuli correctly identified and a response time, the time from stimulus insertion into the oral cavity until identification of shape regardless of whether identification was correct. There is agreement of the use of a three-point scale within the literature. Participants receive two points for correct identification, one point for incorrect identification but their choice is similar to the stimulus and 0 points for incorrect identification of a shape which is not similar to the stimulus (Boliek et al., 2007; Ikebe et al., 2007; Kawagishi et al., 2009; Park, 2017). Some literature reports an overall score, the total number of points and/or the total time, (Boliek et al., 2007; Kawagishi et al., 2009) while others report scores and response times on individual shapes (Hirano et al., 2004; Ikebe et al., 2007). All literature agrees that a higher score is indicative of better sensory perception.

Whether a gender effect can be found on OSA in participants has been reviewed by numerous studies. All studies agree that there are no gender differences found in OSA between male and female participants (Jacobs & Van Steenberghe, 2006; Kawagishi et al., 2009; Shupe, Resmondo, & Luckett, 2018).

A number of studies have researched the effect of age on OSA. Park (2017) investigated age related changes in OSA in 184 healthy adults aged between 20 years and 89 years. Participants completed a test of OSA with 20 different shapes. Their measures included response time and scores using a three-point rating scale. Results concluded participants in their 20s had the highest scores and fastest response time while participants in their 80's had the longest response time and the lowest scores. No significant differences were found between participants in their 20s and 30s. Park (2017) does not state how participants were grouped by age or the number of participants for each age group. These findings further confirm research by Ikebe et al. (2007) who compared OSA in three groups of healthy participants. Participants were young, dentate participants aged between 24 and 28 years, older dentate individuals aged between 57 and 76 years and older edentulous participants aged between 66 and 88 years. Ikebe et al. (2007) found the younger participants had a significantly shorter response times and higher scores than both edentulous and dentate older adults. Kawagishi et al. (2009) confirms the age effect in OSA when comparing OSA in 269 healthy young participants aged between 23 and 32 years to OSA in 60 healthy older adults aged between 66 to 91 years. The literature agrees that OSA declines with age. This is not surprising as an age effect can be seen in other bodies of literature regarding swallowing. With age comes a loss of muscle strength used in mastication (Cichero, 2018), reduced tongue strength (Fei et al., 2013), loss of teeth, increased swallowing time, delayed onset of the pharyngeal swallow and increased post-swallow oral and pharyngeal residue (Humbert et al., 2009b). These declines are similar to what is expected in other bodily functions, such as gait and mobility (Cichero, 2018).

A body of research has sought to understand the impact of dentures and palatal coverage on oral sensation and OSA. Ikebe et al. (2007) compared OSA in dentate and edentulous participants who wore full upper and lower dentures for longer than three months. Their results found no significant difference in score and response time when comparing the dentate and edentulous participants. This literature contributes to a growing body of literature that palatal coverage and dentures do not impact OS score and response time (Kawagishi et al., 2009; Kumamoto et al., 2010; Pow et al., 2001). Interestingly, Meenakshi et al. (2014) studied OSA in 30 participants prior to denture insertion, 30 minutes post insertion and one month after denture insertion. For OS they used 20 shapes commonly used within the literature (Kawagishi et al., 2009; Meenakshi et al., 2014; Park, 2017; Shetty et al., 2007). Results demonstrated OSA identification scores significantly increased (73.3% pre-insertion, 76.7% 30 minutes post-insertion and 85.6% one month post-insertion).and response time significantly decreased from prior to insertion and 30 minutes post insertion to one month post insertion.

These results challenge the prior research who found no significant difference when comparing dentate and edentulous participants (Kawagishi et al., 2009; Kumamoto et al., 2010; Pow et al., 2001). Despite this, the research agrees that palatal coverage and dentures have no negative impact on OSA. This research suggests that sensory perception in the palate is not as important as other sensory receptors in the oral cavity for OSA.

The tongue has an important role in OS in both the physical manipulation of the stimuli and providing sensory information to identify the stimuli shape. Steele et al. (2014) investigated the influence of lingual strength on lingual tactile acquity. A total of 78 healthy adults, 39 under the age of 40 and 37 over the age of 60 years, completed two tasks. Firstly, a test of tongue strength using the lingual pressure module on the KayPentax Swallowing Signal Lab which requires a placement of a silicone strip with three pressure bulbs stuck to the midline of the palate. Participants were asked to "squeeze the air out of the pressure bulb as hard as possible using your tongue." This was repeated five times and the highest pressure amplitude was used. Secondly, participants completed an OS task using letter identification. A Teflon strip with a letter was placed against the alveolar ridge and participants used their tongue to identify the letter. Participants moved up and down various letter sizes from 2mm to 8mm until they had 8 consistent responses on one size. They found that participants with relatively poor tongue strength were able to complete the OS task when compared to participants with good tongue strength. This leads to a conclusion that maximum lingual strength is not necessary for OSA. The findings that the tongue, although important in OS, does not require maximal strength can be correlated to that of swallowing where swallowing does not require maximal tongue strength (Park, Oh, & Chang, 2016)

Oral sensory receptors are important for the mastication of food. These sensory receptors perceive characteristics on the bolus and use this sensory information to coordinate the manipulation and mastication of the bolus into a cohesive bolus which is ready for swallowing (Hirano et al., 2004). Hirano et al. (2004) aimed to investigate the relationship between masticatory efficiency and oral stereognosis. Their participants consisted of 30 young, dentate participants aged between 24 and 28 years, 20 older, dentate participants and 30 older, edentulopus participants. Older participants were aged between 57 years and 88 years.

Participants completed an OS task using six different shapes. Response times and OS score was recorded. Participants then completed a masticatory function test to evaluate masticatory performance and masticatory efficiency. To evaluate masticatory performance participants were required to masticate 3grams of peanuts for 20 masticatory cycles. The participants then expectorated, sieved using a 10-mesh sieve, dried and measured. Particles bigger than 1700 mesh open were weighed. To evaluate masticatory efficiency participants masticated 3 grams of peanuts for 5, 10, 15, 20 and 30 masticatory cycles. After each number of masticatory cycles were completed the participants then expectorated the bolus for it to be sieved, dried and weighed.

Hirano et al. (2004) reported a significant positive correlation in their results between masticatory efficiency and OS score; however, no significant correlation was found between masticatory ability and OSA response time. Another study by Kumamoto et al. (2010) also used the sieve method to look at masticatory efficiency and OSA in 15 young, healthy adults aged between 22 and 32 years. Their study replicated the shapes and sieving method for masticatory efficiency as described by Hirano et al. (2004). This study aimed to understand the effect of palatal coverage on OSA and masticatory efficiency. There were three conditions to the study. Participants wore no palatal plate, participants wore a plate which fully covered the palate and participants wore a horse-shoe shaped palatal plate which partially covered the palate. All participants completed all three trials. Their results found a significant positive correlation between masticatory efficiency and OSA when participants were not wearing a palatal plate and when the palate was only partially covered. These results further confirm Hirano et al. (2004) and suggest that higher OSA is indicative of increased masticatory efficiency. A limitation of these studies is that the sieving method for assessing masticatory efficiency is not a functional assessment of swallowing and is not used clinically with patients. While these studies provide some information regarding the relationship between masticatory efficiency and OSA there is yet to be a link between OSA and functional assessments of swallowing. More research is needed to explore this relationship further.

There are currently few studies which have reported on the impact of stimulus size on OSA. Hirano et al. (2004) explored two sizes in a set of six simple shapes. Large sizes were 12 mm x 12 mm x 3 mm and small pieces were 8 mm x 8 mm x 2 mm. Fifteen healthy participants, aged between 24 years and 29 years were recruited for this assessment of OSA. Each shape form was repeated three times, although the authors do not report whether shapes were randomised and if participants received one stimulus size at a time. Their results found that OS score was lower and response times were shorter on smaller stimuli than larger stimuli but the significance for these was not found to be statistically significant among the pieces.

Ikebe et al. (2007) replicated the shapes and sizes used by Hirano et al. (2004) with 30 young, dentate, participants aged between 24 to 28 years, 20 older, dentate participants and 30 older edentulous participants. Older participants ages ranged from 57 year to 88 years. Participants were presented each stimulus twice and scores and response times were recorded. The authors found large stimuli had a higher score and shorter response time than small stimuli. The authors do not report if this finding was found across all age groups. There is currently limited research on the effect of stimulus size on OSA. This is a significant gap within the literature which has yet to be addressed.

There is currently some literature available regarding OS although more literature is needed to further explore and understand oral sensation and OS as an assessment of oral sensation. There is limited literature available on the effect of size on OSA and there is no research currently available which evaluates OSA with functional assessments of swallowing.

2.3 Timed Water Swallowing Test

A timed water swallowing test (TWST), developed by Nicklin, Nathadwarawala, and Wiles (1992), is used to evaluate swallowing capacity. Participants were given 150mls of water in a glass and asked to drink "as quickly as possible." The observer counts the total number of swallowing events and the total time taken to complete the task.

Nicklin et al. (1992) evaluated reliability, validity and a guideline of normative data. Interrater reliability was assessed by six examiners timing five videos of participants performing the TWST twice, with the face of the stopwatch hidden. The differences of time in interrater reliability was between 0.0 and 0.5 seconds, indicating a high interrater reliability. Intrarater reliability was assessed by 24 participants completing the TWST four times over a 48 hour period, with two flavoured drinks. Flavour had no significant effect on performance. No significant effect was found on swallowing speed across the four trials, finding a high intrarater reliability.

Nicklin et al. (1992) developed guidelines for normative swallowing speed through completion of the TWST in 101 healthy participants. Results demonstrated that swallowing speed declined in males and females with age. On average, females drank slower than males. No participants, regardless of gender, under the age of 70 years drank slower than 10.7ml/s. Nicklin et al. (1992) classify their age groups for male and females as over 70 year and under 70 years. There is no discussion on performance variations with more specific age norms. Normative data and age variations were further studied by Hughes and Wiles (1996) who evaluated the TWST in 181 healthy adults, aged from 15 years to over 75 years using 10 year age bands with a minimium number of 10 males and/or females in each age band. Hughes and Wiles (1996) expanded the outcome measures for the TWST using raw data measures, number of swallowing events and total time to calculate derived measures of volume per swallow, time per swallow and volume per time. Their results found that men had a increased volume per swallowing and swallowing capacity but a decreased time per swallow when compared to women. They found that volume per swallow and swallowing capcity declined with age in both men and woment while time per swallow increased with age in both genders.

Gender was further researched by Alves, Cassiani, Santos, and Dantas (2007) who used a 50ml water swallowing test with 111 healthy participants between 22 and 77 years of age. Their results affirmed Hughes and Wiles (1996) results finding that women had smaller volume capacity and slower swallowing velocity. Interestingly, Alves et al. (2007) found that women had a shorter inter-swallow interval compared to men and height and body mass index did not impact results.

Wu, Chang, Wang, and Lin (2004) further evaluated the sensitivity and specificity of using a 100ml water swallowing test to detect swallowing dysfunction. Fifty-nine adults, who were referred for a videofluroscopic evaluation of swallowing (VFSS) for a suspected swallowing dysfunction, were asked to complete a 100ml water swallowing test 24 hours prior to completing a VFSS. Results demonstrate that of the 55 patients identified with a swallowing impairment by VFSS, 49 of them had been identified as a potential swallowing dysfunction in the 100ml water swallowing test. They found that the water swallowing test had a 85.5% sensitivity and 50% specificity at detecting swallowing dysfunction when compared to the VFSS. These results further affirmed Hughes and Wiles (1996) who reported patient's with motor neurone disease who reported swallowing difficulties had smaller bolus volumes, spent more time on each swallowing cycle and had reduced swallowing capacity. Their conclusions were that a water swallowing test is a beneficial tool for screening for swallowing dysfunction.

The TWST has been shown to be a easy, reliable and effective measure of swallowing efficiency. The TWST measures sequential swallowing of liquid which is a typical pattern of swallowing behaviour in adults (Murguia, Corey, & Daniels, 2009; Veiga, Fonseca, & Bianchini, 2014). It is more abnormal for adults to take single swallows for the ingestion of liquids and studies show that sequential swallowing is different to single swallows (Murguia et al., 2009; Veiga et al., 2014). The TWST is therefore able to assess the more natural method of swallowing, sequential. However, there are some limitations to the TWST, firstly, many dysphagic patient's have difficulty swallowing thin liquids. The TWST require sequential swallowing of 100-150mls of water, which is not an appropriate assessment measure for patient's with difficulty swallowing thin liquids. Secondly, although it has been established that the TWST is a reliable and effective measure of swallowing, it does not challenge the oral phase of swallowing. A liquid bolus requires no mastication, a shorter oral transit time, decreased oral pressure and decreased time in the phases of swallowing (Daniels et al., 2019).

2.4 Test of Mastication and Swallowing Solids

The Test of Mastication and Swallowing Solids (TOMASS) was developed as an adjunct tool to the TWST developed by Hughes and Wiles (1996) to assess the swallowing rate of solid bolus texture. Originally the TOMASS was developed by Athukorala, Jones, Sella, and Huckabee (2014) as an outcome measure of their study on swallowing rehabilitation using skill training in patients with Parkinson's Disease. The TOMASS allows for a quantitative measure of oral phase efficiency during ingestion of solid bolus texture. Patients are given a quarter (1 portion) of a Arnotts Salada Cracker and asked to ingest the cracker "as quickly as is comfortably possible." Measurements take include the number of discrete bites taken to eat the entire cracker, the number of masticatory cycles to ingest the cracker, the total time taken to complete the task was recorded and the total number of swallowing events was counted. (Athukorala et al., 2014).

Huckabee et al. (2018) established reliability, validity and international normative data through four projects. The first phase of the research trail involved three projects and a total of 228 healthy participants. Trial effect, age and gender differences and cracker differences were evaluated with 84 adults, evenly distributed by gender, in four age brackers from 20 years to over 80 years. A trial effect was noted and data from trial one was used for data analysis. A significant age effect was found on all raw data measures, with increasing age associated with increased mastication and time. A significant gender effect was recored on all raw data measures. Male participants, when compared to age equivalent females, demonstrated fewer bites, masticatory cycles, swallowing events and a shorter time to complete the task.

A further 80 participants, balanced by age and sex, were recruited to trial the TOMASS using a different cracker, the Nabisco Saltine cracker, as the Arnott's Salada Cracker is not commercially available worldwide. The Nabisco Saltine cracker and the Arnott's Salada cracker are almost identical in size, shape and appearance and contain similar ingredients. Significant differences between crackers was notes with participants ingesting the salada cracker requiring increased bites, masticatory cycles, swallowing events and more time to ingest the cracker.

Huckabee et al. (2018) evaluated test-retest and interrater reliability with 40 additional healthy participants, equally distributed by sex and the four age bands. Participants completed the TOMASS using the Arnott's Salada cracker twice in a single session across three consecutive days. Two raters were present for one session to collect the four raw TOMASS measures to assess interrater reliability. Participants were allowed sips of water to clear any oral residue and moisten mucosa between the two trials. A within- session trial effect was observed and the second trail consistently demonstrated fewer masticatory cycles and swallowing events and a faster total time. Interrater reliability was high (>.90) for all measures, supported with ICC values >.98 and test-retest measures across sessions were also very high with ICC values ranging between .83 and .98.

The third project by Huckabee et al. (2018) evaluated the validity of the TOMASS and 24 health participants, evenly distributed by sex across the four age bands used in the previous three projects, were recruited. Participants ingested an Arnott's Salada cracker twice in a single session. Participants returned at least 24 hours following the first session to complete the TOMASS twice more. The placement of sEMG electrodes allowed for the collection of objective measures of both mastication and swallowing. The ICC value between objective and behavioural measures for the total number of masticatory cycles was .99, for the total number of swallowing events ICC was .85 and for time ICC was .99. The reliability of two independent raters of masticatory cycles and total time had an ICC of .95 and interrater reliability for number of swallowing events ICC was .73.

In phase two of the research programme Huckabee et al. (2018) established normative data for commerically available crackers in seven regions worldwide. Each international database had a mininmum of 80 healthy participants across the four age bands used in the previous three projects. The Arnott's Salada cracker was used for normative data for Australia/New Zealand, the Nabisco Saltine was used for normative data in North America, Carr's Table Water cracker was used for normative data in Ireland and the United Kingdom, Albert Heijn Basic cracker was used for normative data in the Netherlands, in Germany the DeBeukelaer Tuc Classic was used for normative data, Gran Pavesi cracker was used for normative data in Italy and Portugal and the Osem Golden cracker was used for normative data in Isreal.

Further research on the TOMASS completed by Lamvik-Gozdzikowska, Guiu Hernandez, Apperley, McIntosh, and Huckabee (2019) evaluated the sensitivity of the TOMAS to changes in the oral-phase preparation when topical anethesia was used. Ten healthy participants, evenly distributed by sex, aged between 19-24 years were recruited. Participants completed the TOMASS three times, pre-anaesthesia, with anaesthesia and post-anaesthesia and were given a glass of water to consume between each trial. The oral mucosa was anaesthesitised by the application of 0.8ml of topical anaesthetic gel ZAP. Results demonstrated there was no statistically significant change in the the total number of bites and swallowing events across all three trials. Under the anaesthetic trial there was a significant increase in the number of masticatory cycles and the total time taken to ingest the cracker. The study demonstrates that the TOMASS may be a sensitive measure for the assessment of oral phase preparation of solid textures.

Different materials have been used in assessment of mastication including peanuts and carrots (Manly, 1951), silicone (van der Bilt, Olthoff, Bosman, & Oosterhaven, 1994), chewing gum (Molenaar et al., 2012) and wax (Sueda et al., 2003). Previous methods describe a sieving method where the 'bolus' is masticated for a certain number of times then expectorated. The bolus was then washed, dried, sieved and measured. The degree of breakdown within the bolus could then be used to describe masticatory ability. However, none of these materials are easily measured, recreated and some are not edible. Even the use of peanuts can come in various sizes. Having limited control on the physical properties of the bolus would make it difficult to recreate and use consistently during a swallowing assessment with patients. Some of these materials would be considered a choking hazard for patients and therefore would not be recommended for use with people with swallowing difficulties. The TOMASS by comparison has normative data in a variety of crackers found worldwide, which are easily distributed. The protocol for the TOMASS can be done at patient bedside and requires no materials that may not be readily available for the clinician. The involvement of swallowing during the TOMASS enables clinicians to relate mastication and preparation with swallowing. The TOMASS emphasises the oral phase and bolus preparation in swallowing (Huckabee et al., 2018). A limitation of the TOMASS is that it does not provide sensitivity on the pharyngeal phase of swallowing. Future research may explore the TOMASS and pharyngeal phase of swallowing.

2.5 Objectives and Hypotheses

2.5.1 Study Objective

The objective of this study was to increase the current understanding of the relationship between oral sensation and swallowing in healthy adults aged 55 years and older.There is some thought that oral stereognostic ability could be used to assess oral sensation. This study will investigate the effect of form size on OSA using 20 shapes seen in the literature. This study will also explore whether any significant correlations exist between OSA and clinically used assessments of dysphagia, TOMASS and TWST as this is an area that has not been identified in any literature to date. This study investigates whether a statistically significant correlation exists between masticatory ability and OSA using a different measure of mastication. The rationale for this is that oral sensation informs when sufficient mastication of the bolus has occurred and the bolus is ready for bolus transfer through the pharynx.

2.5.2 Research Question 1

Question: Does stimulus size effect OSA in healthy participants aged 55 years and older?

Hypotheses:

1. Participants will demonstrate a higher OSA score on larger stimuli than smaller stimuli.
2. Participants will demonstrate a faster response time on smaller stimuli than larger stimuli.

2.5.3 Research Question 2

Question: Is there a significant correlation between OSA and the scores from TOMASS and the TWST in healthy participants aged 55 years and older?

Hypotheses:

1. There will be a significant negative correlation between OSA and measures on the TOMASS. Participants with a lower OSA score will demonstrate increased measures on the TOMASS. Specifically, there will be increased number of bites, increased

number of masticatory cycles, increased number of swallowing events, increased time taken to complete the task.

2. There will be a significant positive correlation between OSA and measures on the TWST. Participants with a lower OSA score will demonstrate lower measures on the TWST. For example: decreased volume per swallowing event and decreased swallowing capacity.

Chapter 3: Methodology

3.1 Ethical Considerations

Ethical approval was received by the University of Canterbury Human Ethics Committee prior to the commencement of data collection. All participants were provided with written and verbal explanations of the study procedures and provided with opportunities to ask questions. They each signed a consent form prior to commencement of data collection.

3.2 Participants

Fifty healthy participants (M=20, F=30) aged 55 years and older were recruited to take part in this study. Sample size was calculated for a small and medium effect size using G*Power. For a medium effect size (0.30), using a significance of 0.05 and a power of 0.8, 84 participants were required. For a small effect size (0.10), using a significance of 0.05 and a power of 0.8, 29 participants were required. For this study, 50 participants were recruited to allow for at least moderate power within the time frame available for recruitment. Participants were recruited through the participant database at the Rose Centre for Stroke Recovery and Research, flyers placed in community centres and community groups.

<u>Inclusion Criteria:</u> Healthy adults aged 55 years and older who were able to give informed consent to participate and who reported no previous or current swallowing difficulties.

<u>Exclusion Criteria:</u> Any participant was excluded who reported inclusion of any of the following in current or past medical history: stroke, swallowing difficulties, dementia, any brain related condition or illness causing brain injury, pain or problems with jaw, temporomandibular joint or chewing, head and/or neck injury/surgery, head and/or neck cancer, neurological disorders, muscular disease, significant visual impairments, coeliac disease or following a gluten free diet.

3.3. Procedures

Participants attended one assessment session in which all tasks were completed. Participants were welcomed and seated comfortably upright in a chair. Following provision of informed consent, participants completed three tasks: a test of Oral Stereognosis, the Timed Water Swallowing Test (TWST) and the Test of Mastication and Swallowing Solids (TOMASS)

3.3.1 Oral Stereognosis

Stimuli Description: Stimuli consist of 20 different polyethylene shapes, which are standard in this area of research (Kawagishi et al., 2009; Park, 2017; Weinburg, 1967). However, unique to this project was the inclusion of three sizes of each shape. Set 1 stimuli were 15mm in length and 4.5mm thick. Set 2 stimuli were 10mm in length and 3mm thick and set 3 stimuli were 5mm in length and 1.5mm thick. Thus, there were 3 sets of 20 stimuli. A length of Reach Cleanburst™ spearmint waxed dental floss was used to secure the stimuli to the participants clothing to mitigate risk of swallowing or choking on the stimuli.

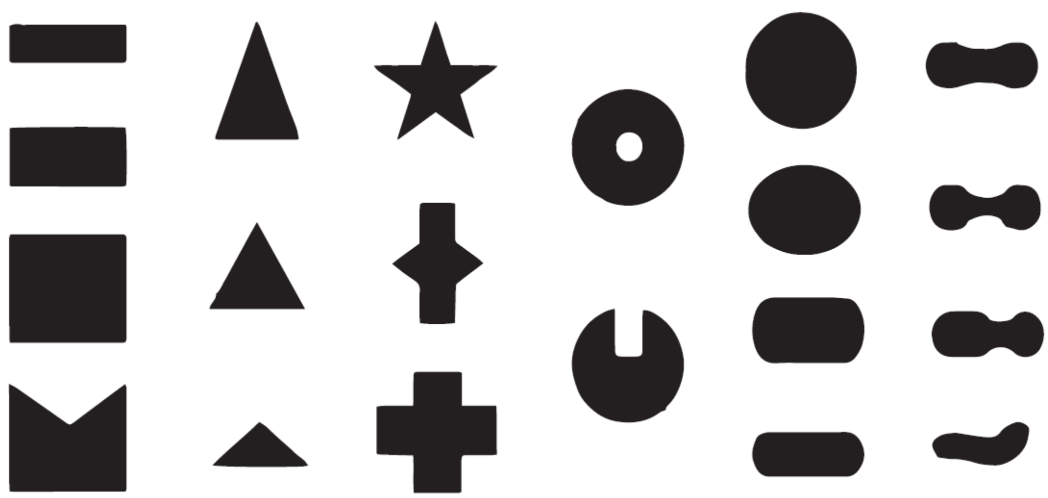

Figure 1. *Shape Chart used in Test of Oral Stereognosis*

Assessment Protocol:

The participant was seated comfortably in a chair at a table with an A4 printed shape chart (Figure 3.1) placed directly in front of them. All participants had access to water and tissues at all times throughout the session.

All participants were given the same instructions for the task. Participants were told they were able to open their eyes as soon as the stimulus was placed in their mouth. Participants were instructed they were able to use any part of their mouth to identify the shape- including teeth, tongue and palate. The participant was asked to close their eyes. The researcher then placed a stimulus item into the participant's mouth using sterilised tweezers; the item, threaded with dental floss, was attached to a peg to the participant's clothing. The participant then identified the stimulus item by pointing to the corresponding shape on the shape chart placed in front of them. A stopwatch was used to document the time the stimulus entered the mouth until the selection of the corresponding shape. Once the participant chose a shape, they were asked to close their eyes and the primary researcher removed the stimuli. This process was repeated for each of the 20 stimuli, in all 3 sets. The order the sets were presented was randomised and participants were presented one set of stimuli at a time. The order the 20 stimuli within a set were presented was randomised. Participants were given up to a 1 minute break after each set. Participants were told that if they needed a break prior to finishing a set to tell the primary researcher.

All equipment was sterilised between patients. Sterilisation of all equipment included soaking the stimuli in Medizyme, a neutral enzyme cleaner, diluted in water for 2 minutes. The equipment was then sterilised using Milton tablets, hospital grade antibacterial tablets, for a minimum of 15 minutes. The dental floss was discarded at the end of each session. Gloves were changed between participants.

3.3.2 Timed Water Swallowing Test

Following the protocol outlined in Hughes and Wiles (1996), the researcher measured 150mls of water into a beaker and then transferred this water into a disposable cup. Participants were instructed to drink this water "as quickly as is comfortably possible." The researcher video recorded the lower portion of the participants face using an iPad. In this protocol, all participants received 150mls of water which is slightly different from the protocol described by Hughes and Wiles (1996) where participants over the age of 75 years receive 100mls of water. As the purpose of this study is not to compare data collected from this participants to normative data described by Hughes and Wiles (1996) but to investigate whether any correlations exist between test of OS and the timed water swallow test it was concluded that it is more reliable to use the same amount of water for all participants.

3.3.3 Test of Mastication and Swallowing Solids

Following the protocol outlined in Huckabee et al. (2018) participants were given ¼ of an Arnotts Salada Cracker and asked to "eat this as quickly as is comfortably possible. When you have finished, say your name." The researcher video recorded the lower portion of the participants face using an iPad.

3.4 Data Extraction

All data was collected and extracted by the primary researcher. The following data measures are described below:

3.4.1 Oral Stereognosis

During the session, participant answers were scored using a three-point scale as described in the literature (Hirano et al., 2004; Ikebe et al., 2007; Kumamoto et al., 2010; Park, 2017). For this scale, participants were scored 2 points for a correct identification, 1 point for an incorrect identification but with a choice within the same 'shape group' and 0 points for incorrect identification outside of the ‘shape group.’ A total score out of 40 points was calculated for each set of stimuli. The total time taken was also calculated by adding all of time measures for each of the 20 stimuli in all three sets.

3.4.2 Timed Water Swallow Test

Following data collection raw measurements were extracted of total time taken to complete the test and the total number of swallowing events needed to complete the task. These measurements provided the following derived measures of oropharyngeal swallowing: volume per swallow, time per swallow and volume over time (Hughes & Wiles, 1996).

3.4.3 Test of Mastication and Swallowing Solids

Following data collection raw measurements were extracted. These included the number of discrete bites taken to ingest the cracker, the number of masticatory cycles, the number of swallowing events, and the total time to complete the test.

3.5 Data Analysis

IBM SPSS was used for statistical analysis. A one way multivariate analysis of variance (MANOVA) was used to determine the effect of stimulus size on the variables of oral stereognostic score and response time.

Pearson’s Correlation coefficient was used to investigate the relationship between oral stereognostic measures of scores and response time in all stimulus sizes, raw data measures of the TOMASS and derived data measures of the TWST. Raw data measures for the TOMASS included number of swallowing events, number of masticatory cycles, number of bites to ingest the cracker and total time taken to complete the task. Derived measures of the TWST use raw data measures number of swallowing events and total time taken to complete the task to calculate volume per swallow, time per swallow and volume per time. Pearson’s correlation coefficient was also used to investigate the strength of the relationship between oral stereognostic score and response time in all stimulus sizes. Significance was set as $p = < 0.05$ for all statistical analysis.

Chapter 4: Results

4.1 Participants

A total of 50 participants participated in this study, aged between 56 and 86 years. There were 20 male participants and 30 female participants. Four participants reported a transient ischemic attack (TIA) in their medical history; all were at least 3 years prior to participation in the study. One participant reported they had idiopathic tracheal stenosis. One participant reported a non-malignant tumor removed on the left side of their neck not affecting any internal structures. Forty participants had their own teeth, two participants had full upper and lower dentures, eight participants had partial dentures. Three participants reported they had several missing teeth. All participants reported no current or previous difficulty swallowing.

4.2 Stimulus size and oral stereognostic score

Figure 2 shows the effect of stimulus size on oral stereognostic score. A mean score and 95% confidence interval was calculated for all stimulus sizes. The mean score increased as the size of the stimuli increased. Small stimuli had the lowest mean score, M = 13.38, 95% CI [11.47, 15.09]. Participants scores increased with medium stimuli, M = 26.86, 95% CI [25.05, 28.67]. Large stimuli had the highest mean score, M = 30.14, 95% CI [28.33, 31.95].

The mean difference between small stimuli with medium and large stimuli was statistically significant at $p = < .001$. The mean difference between medium and large stimuli was statistically significant, $p = .012$.

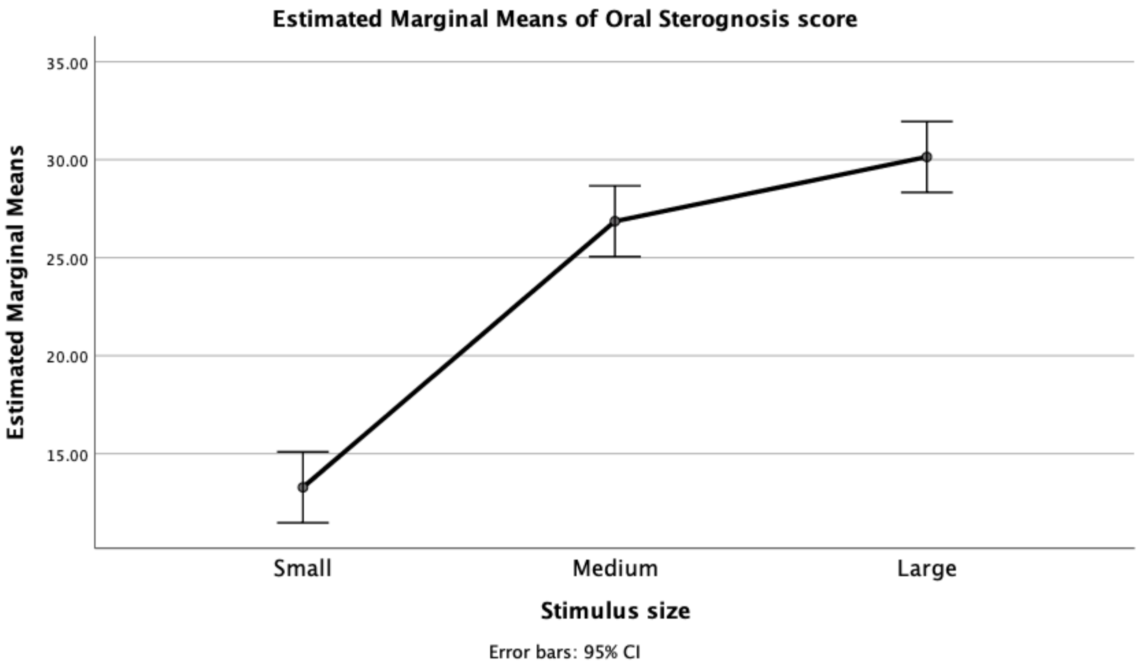

Figure 2. *Effect of Stimulus Size on Mean Oral Stereognostic Scores with 95% Confidence Intervals.*

4.3 Stimulus size and oral stereognostic response time

Figure 3 shows the effect of stimulus size on oral stereognostic response time. A mean response time and 95% confidence interval was calculated for all stimulus sizes. Small stimuli had the slowest mean response time, M = 499.63 seconds (s), 95% CI [441.95s, 557.31]. Participant response times were faster for medium stimuli, M = 324.21s, 95% CI [266.53s, 381.89s]. Large stimuli had the fastest response times, M = 281.78s, 95% CI [224.10s, 339.46s]. Medium and large response times were not statisitcally signicant, p = .306. Response time for small stimuli was signifcantly different to response times for medium and large stimuli, p = < .001.

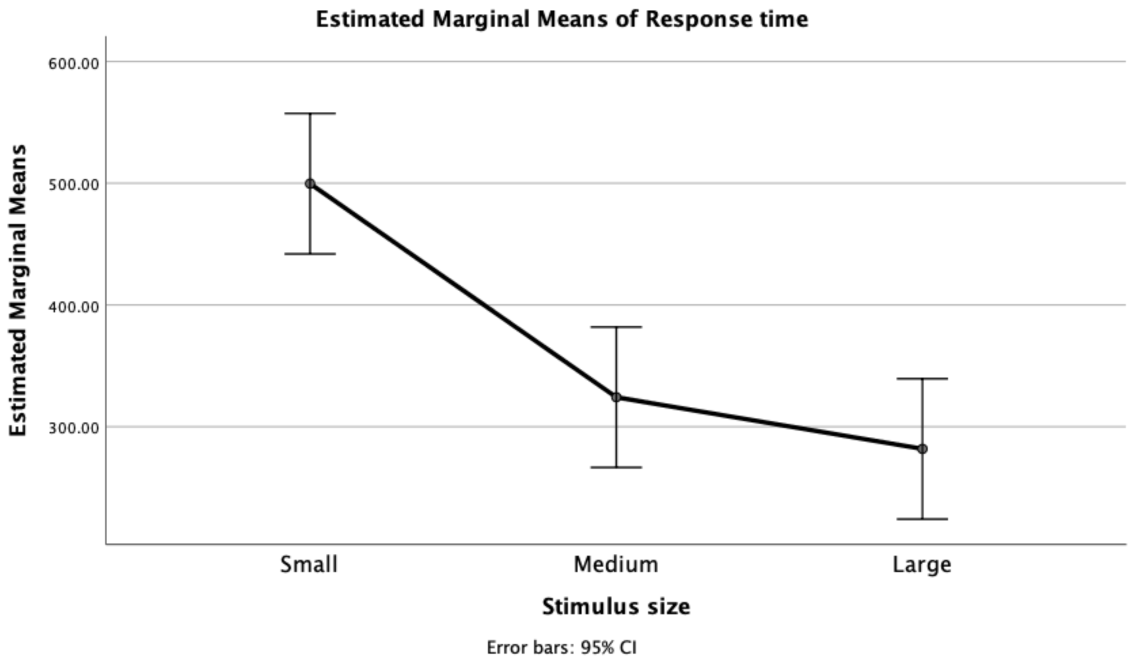

Figure 3. *Effect of Stimulus Size on Mean Response Time with 95% Confidence Interval.*

4.4 Correlation between OSA and TOMASS

Correlations were calculated between oral stereonostic varibales and measures of the TOMASS. Oral sterognostic variables were time and score in all stimuli sizes (small, medium, large). Measures for the TOMASS included of the number of swallowing events, number of masticatory cycles, number of bites and total time taken to ingest the Arnotts Salada cracker. As there was no statistically significant difference in response times for medium and large stimuli sizes, a single measure for response time was created by calculating a mean score.

4.4.1 Oral Stereognostic Score

Some significant corelations were identified between participant scores on each of the three stimulus sizes and measures of swallowing from the completion of the TOMASS. Table 1 illustrates these statistical correlations. A moderate negative correlation (r = -.302, p = .033) was found between the oral stereognostic score on small stimuli and the number of swallowing events. A moderate negative correlation was found between the oral stereognostic score on medium stimuli and the number of masticatory cycles (r = -.457, p = .001) and on total time (r = -.379, p = .007).

Table 1 demonstrates statistically significant correlations were found between oral stereognostic score on large shapes and all measures from the TOMASS. Moderate negative correlations were found between oral stereognostic score on large stimuli and the number of masticatory cycles (r = -.403, p = .004) and total time (r = -.437, p = .002). Alongside this, small negative correlations were found between oral stereognostic score on large stimuli and number of swallowing events (r = -.284, p = .046) and number of bites (r = -.297, p = .036).

Table 1. *Correlations between Oral Stereognostic Scores and Measures of the TOMASS*

	Pearson Correlation	*Sig. (2-tailed)*
Small Stimuli Score		
Number of swallows	**-.302**	**.033**
Number of Masticatory cycles	-.231	.107
Number of bites	-.182	.205
Total time	-.278	.051
Medium Stimuli Score		
Number of swallows	-.099	.496
Number of Masticatory cycles	**-.457**	**.001**
Number of bites	-.235	.100
Total time	**-.379**	**.007**
Large Stimuli Score		
Number of swallows	**-.284**	**.046**
Number of Masticatory cycles	**-.403**	**.004**
Number of bites	**-.297**	**.036**
Total time	**-.437**	**.002**

4.4.2 Oral Stereognostic Time

Table 2 shows correlational statistics between oral stereognostic time measures and measures of the TOMASS. This table shows that two moderate statistically significant correlations were found between oral stereognostic time between small stimuli and bites (r = -.411, p = .003) and oral stereognostic time on medium/large stimuli and bites (r = -.300, p = .034).

Table 2. *Correlations between Oral Stereognostic Measure of Time and Measures of the TOMASS*

	Pearson Correlation	*Sig. (2-tailed)*
Small Stimuli time		
Number of swallows	.044	.763
Number of Masticatory cycles	-.118	.415
Number of bites	**-.411**	**.003**
Total time	-.302	.824
Medium/large stimuli time		
Number of swallows	.102	.482
Number of Masticatory cycles	.078	.591
Number of bites	**-.300**	**.034**
Total time	.186	.197

4.5 Correlation between OSA and TWST

Correlations were calculated between oral steregonostic variables and derived outcome varaibles of the TWST. Oral sterognostic variables were time and score in all stimuli sizes (small, medium, large). Derived outcome measures of the TWST included volume per swallow, time per swallow and volume per time. A medium/large measure for response time was used as described above.

4.5.1 Oral Stereognostic Score

Table 3 illustrates correlational statistics between oral stereognostic scores and measures of the TWST. Some statistically signifcant correlations were found. Three moderate negative correlations were found between time per swallow and oral stereognostic score of small stimuli (r = -.378, p = .007), medium stimuli (r = -.333, p = .018) and large stimuli (r = -.311, p = .028). Additionally a small postive statistically significant correlation was found between oral steroegnostic score of large stimuli and volume per time (r = .289, p = .042).

Table 3. *Correlations between Oral Stereognostic Scores and Measures of the TWST*

	Pearson Correlation	*Sig. (2-tailed)*
Small Stimuli Score		
Volume/swallow	-.118	.415
Time/swallow	**-.378**	**.007**
Volume/time	.194	.176
Medium Stimuli Score		
Volume/swallow	.044	.761
Time/swallow	**-.333**	**.018**
Volume/time	.243	.090
Large Stimuli Score		
Volume/swallow	.074	.609
Time/swallow	**-.311**	**.028**
Volume/time	**.289**	**.042**

4.5.2 Oral Stereognostic Time

Table 4 demonstrates that no statistically significant correlations were identified using small stimuli time and medium/large stimuli time with measures of the TWST.

Table 4. *Correlations Between Oral Stereognostic Measures of Time and Measures of TWST*

	Pearson Correlation	*Sig. (2-tailed)*
Small Stimuli time		
Volume/swallow	.239	.095
Time/swallow	-.008	.957
Volume/time	.094	.517
Medium/Large Stimuli time		
Volume/swallow	.198	.168
Time/swallow	.116	.422
Volume/time	-.006	.964

Chapter 5: Discussion

The primary aim of this study was to increase our current understanding of the relationship between oral sensation and swallowing. This study explored oral sensation through the use of OS in healthy adults and then correlated results from these to functional assessments of swallowing (the TOMASS and the TWST) used by clinicians with patients with swallowing difficulties. The results of this study demonstrate some statistically significant findings for both research questions. Firstly, the results demonstrate that OS score increased and response time decreased as the size of the stimuli increased. Secondly, some statistically significant correlations were found between OS score and response time and measures of the TOMASS and the TWST. No significant correlations were found between OS response time and measures of the TWST.

5.1 OSA

This study aimed to answer two questions. Firstly, does stimulus size effect OSA in healthy participants over the age of 55 years? We hypothesised that participants would score higher, participants would be more accurate, during the assessment of OSA on larger stimuli when compared to the smaller stimuli. The second hypothesis was that participants would demonstrate a faster response time on smaller stimuli than larger stimuli. The results from this study support these hypotheses. The results demonstrate that OS score increases significantly with each increase in stimulus size. Response time was longer on medium and large stimuli when compared to small stimuli. The response time for large and medium stimuli were not significantly different to one another.

Previous studies on the effect of stimulus size on OSA report similar findings to the current study. Hirano et al. (2004) compared large stimuli of 12mm x 12mm x 3mm and small stimuli of 8mm x 8mm x 2mm with the same methods of recording OSA score and response time.

They found that participants were more accurate and had a longer response time on larger test pieces, however they report no significance was found among the test pieces. These results, although consistent with the findings from the current study, were not statistically significant. There are a few reasons why this may have occurred. Firstly, Hirano et al. (2004) had a small sample size of fifteen participants who were aged between 24 and 29 years. Previous research by Ikebe et al. (2007) demonstrates that OSA declines with age and older participants have a significantly lower OS score and a significantly longer response time. This is further confirmed by Park (2017), who found that participants in their 20s and 30s had the highest OS score and shortest response time and OSA declined with age. They found that adults in their 80s had the lowest score and longest response time.

Ikebe et al. (2007) compared OSA in young adults aged between 24 and 28 years and older participants aged over 55 year. They compared large stimuli of 12mm in length and small stimuli of 8mm in length following a similar methodology to the present study, including methods of recording scoring and response time. Their results found that large test pieces had a higher OSA score when compared with the smaller test pieces. They do not report whether this scoring is consistent across the two age populations and they do not report whether their results found any effect of stimulus size on response time.

These discrepancies may further exist as the shapes in the current study had a wider variation of stimulus sizes, 15mm, 10mm and 5mm, which are both larger and smaller than the shapes used by Ikebe et al. (2007) and Hirano et al. (2004). Perhaps having a bigger size difference correlates with having more significant results, more accuracy and longer response time on larger stimuli. It is also relevant to note that the current study used a larger number of different shapes, with 20 different shapes used in total. This is compared to Ikebe et al. (2007) and Hirano et al. (2004) who used six different shapes, a circle, oval, square, rectangle, triangle and semi-circle. Perhaps the shapes used by Ikebe et al. (2007) and Hirano et al. (2004) were too easily identifiable in both stimulus sizes, resulting in less significant and definitive results compared to the current study.

In summary, this study adds to the growing body of literature on the effect of stimulus size on OSA. However, there are discrepancies among this literature compared to previous literature which may be explainable. Further literature on size is needed to conclusively affirm this studies significant results on the effect of stimulus size on OSA.

5.2 OSA and the TOMASS

The second research question aimed to explore whether any statistically significant correlations existed between OSA scores and functional assessments of swallowing - the TOMASS and the TWST. The TOMASS is a quantitative measure of oral phase efficiency during solid bolus ingestion of a dry wheat cracker. We hypothesised that there would be a significant negative correlation between OSA and measures from the TOMASS; in other words, poor OSA would result in increased time, number of masticatory cycles and swallows. The results supported this hypothesis and there were a number of significant negative correlations found between measures of the TOMASS and OS score and response time across all stimulus sizes.

A moderate negative correlation was found between OS response time and the number of bites in small and medium/large stimuli. This suggests that participants who had a longer response time required fewer bites to ingest the cracker.

OS score on small stimuli had the fewest correlations with measures from the TOMASS with one moderate negative correlation between the number of swallowing events. Medium stimuli had two moderate correlations between OS score and the number of masticatory cycles and the total time take to ingest the cracker. OS score with large stimuli had the most correlations with the TOMASS across all measures. Two moderate negative correlations were found between OS score and the number of masticatory cycles and total time taken to ingest the cracker while two small correlations were found between the number of swallowing events and the number of bites to ingest the cracker. Participants who had higher OS scores on large stimuli required fewer bites to ingest the cracker, fewer masticatory cycles to break down the cracker, fewer swallows to finish the cracker and overall less time to ingest the cracker. The results also demonstrate that large stimuli had the most correlations with measures from the TOMASS. A potential explanation for this is that the larger stimulus required more manipulation within the oral cavity to identify its shape, much like that of manipulating and forming a bolus within the oral cavity.

The results suggest that a high OS score is indicative of oral phase efficiency. Huckabee et al. (2018) researched the effect of age on performance in the TOMASS with healthy adults ranging in age from 20 years to over 80 years and recorded a significant age effect across all four measures of the TOMASS. Increased age was associated with increased time, swallowing events, bites and masticatory cycles. The participants for the present study were all over the age of 55 years with the oldest participant being 86 years of age. Given the knowledge of the effect of age on the measures of the TOMASS, this may explain the correlations are found between OSA and measures of the TOMASS. Huckabee et al. (2018) also studied the effect of anaesthetic on young, healthy participants' performance on the TOMASS. They found that oral anaesthetic resulted in a significant increase in the number of masticatory cycles and the total time taken to ingest the cracker. They suggested that the TOMASS is a sensitive measure to evaluate oral phase efficiency and suggests the importance of oral sensation in the oral phase of swallowing. We could conclude that potentially OS score is indicative of performance on the TOMASS.

There is no published data on the relationship between OSA and functional swallowing ability. As such, there are few studies with which these results can be compared and contrasted too. Some research has made correlations between masticatory ability and OSA. Hirano et al. (2004) reported finding a significant positive correlation between OS score and masticatory efficiency suggesting that participants who had a higher OSA score also scored higher on the assessment of masticatory efficiency using sieving method. This finding was further established by (Kumamoto et al., 2010) who found a significant positive correlation with OSA score and masticatory efficiency using the sieving method in healthy participants wearing no palatal plate and participants wearing a partial palatal plate.

In terms of clinical value, the results have provided interesting correlations between OSA and measures of the TOMASS. With these significant findings indicating that a higher OS score is also indicative of improved performance on the TOMASS. It stands to reason that an assessment of OSA would be indicative of swallowing performance for the oral phase of swallowing and there may be room for this assessment in swallowing assessments. The assessment of OS is easy to set up, deliver, requires easily found materials and is relatively quick to administer. There may be room for clinical use of as assessment of OSA in swallowing when more research adds to that provided in this study.

5.3 OSA and the TWST

The second functional assessment of swallowing participants completed was the TWST which evaluates swallowing efficiency of a liquid bolus. We hypothesised that there would be a significant positive correlation between OSA and derived measures of the TWST. While there was limited literature available on correlations between masticatory efficiency and OSA there is no current data on whether any correlations exist between OSA and an assessment of liquid bolus swallowing. The results mostly do not support this hypothesis. No significant correlations were found between OS response time and derived measures of the TWST. A significant moderate negative correlation was found between OS score and the derived measure time per swallow from the TWST on all stimulus sizes. In simpler terms, a higher OS score is correlated with a decrease in time per swallow. Participants who had a higher OS score required less time per swallow in the TWST. Additionally a small positive correlation was found between OS score in large stimuli and the derived measure volume per time. Participants who had lower OS scores had a smaller volume of bolus and took more time. These results may indicate that OS score may predict time per swallow in all stimuli sizes and volume per time in large stimuli in the TWST. Potentially participants with a higher OS score may have a greater swallowing efficiency of liquid boluses.

While there are some significant correlations, there are not many. An assessment of OSA assesses oral sensation, with a higher OSA indicating more intact, or in fact a higher, oral sensory ability. A limitation of the TWST is that is does not challenge the oral phase of swallowing as a liquid bolus requires no mastication, a shorter oral transit time, decreased oral pressure and decreased time in the phases of swallowing (Daniels et al., 2019). It could be that the reason for so few correlations between OSA and the TWST is that the TWST is not a sensitive measure to oral sensation and oral phase effieciency. The OS assessment requires the manipulation of the stimulus around the insternal structures in oral cavity, this movement and manipulation is not completed in the sequential swallowing the TWST measures. This would make sense that fewer significant correlations were seen on the TWST. When comparisons were made between OSA and the TOMASS more significant correlations were found as the TOMASS evalautes oral phase efficiency and requires the manipulation and breakdown of a bolus.

5.4 Limitations of the study

There are some limitations to this study that could be addressed. Firstly, the sample size for this study was small (n = 50). With a larger sample size more conclusive and stronger assumptions could be drawn from the results.

Secondly, hand threading each stimulus was time consuming and awkward to secure to the stimuli and pegs. This would not be feasible if this was to be considered for transfer into clinical practice. The impact of the dental floss needs to be considered in terms of the taste of the floss impacting on the sensation and the potential for dental floss to inhibit the participant's ability to manipulate and feel the stimuli inside the oral cavity. Further research may want to consider alternative for reusable and cleanable threading to avoid wastage and the time to thread the shapes.

For the OS task, a total of 60 shapes were used. Each set was randomised so the order participants received the sets was randomised alongside the order participants received the shapes. A learning effect may have the potential to influence results but this has not been researched to date. Lastly, there was limited inter-rater reliability within this study.

5.5 Future directions

This research has increased our current understanding of oral sensation and its relationship with swallowing. However, there are many more questions and future directions that need to be researched. Future studies should consider using larger sample sizes in their exploration on oral stereognosis and oral sensation.

It would be interesting to evaluate whether any correlations would be found between OSA and the functional assessments of swallowing if a younger cohort was targeted as there is less variability in performance of the TOMASS and TWST in younger populations. We know that there is an age effect on swallowing and OSA so it would be interesting to establish whether these correlations could be found in a younger cohort.

It would be beneficial to gather normative data for OSA in healthy adults. The current study provides normative data on healthy adults over the age of 55 years for OSA but more normative data categorised by various age groups would be necessary to fully understand how OSA changes by age. Normative data could then be used comparatively with a cohort of patients who present with swallowing difficulties to tests its validity, reliability and to further understand the practicalities of the potential clinical implications and clinical use with patients. When more research becomes available, it would be interesting to answer an even bigger question of potential to use the tool not only for the assessment of patients but whether any potential exists for this task to be used as a rehabilitation strategy for patients with oral sensory deficits.

There is no doubt that OSA is an area of research where much room exists for research and information development. Oral stereognosis is an area that could have great impact on our understanding of oral sensation, its role in swallowing and the ability to use OS with patients with swallowing difficulties if more research is made available.

5.6 To conclude

Oral sensation and its role in swallowing has been further researched in the current study through the use of OS and functional assessments of swallowing. Results conclude there is a significant effect of stimulus size on OSA and there are several significant correlations between OSA and functional assessments of swallowing. This study has found that OSA may be an indicator of performance on the TOMASS and the TWST indicating the important role of oral sensation in the oral phase of swallowing. More research is needed to continue developing and extending our current knowledge of the relationship between oral sensation and swallowing through OSA.

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Chapter 6: Appendices

Apendix 1: Information Sheet

Department: School of Psychology, Speech and Hearing co-hosted with the Rose Centre for Stroke Recovery and Research
Telephone: +64 3 369 2385

Email: georgia.holland@pg.canterbury.ac.nz

19.08.2019
HEC Ref: HEC 2019/97

Information Sheet for Participants

The relationship between oral sensation and swallowing

My name is Georgia Holland and I am a Speech Language Therapist Master's Degree at the University of Canterbury Rose Centre for Stroke Recovery and Research under the supervision of Professor Maggie-Lee Huckabee.

My research seeks to understand the relationship between sensation in the mouth and swallowing in adults. Oral sensation is necessary for safe swallowing. However, when swallowing is impaired, traditional assessment and treatment focuses on motor movement, muscle strength and co-ordination. There is limited research on the exact role of sensation in swallowing and how to assess and treat patients with sensory impairment.

One way to assess oral sensation is to use small shapes. The shape is placed in the mouth, without viewing it, and the person uses their mouth and tongue to identify the shape and then point to a corresponding picture.

This study will explore oral sensory ability in adults aged 55 years and older. This study will explore whether the size of a shape effects oral sensation. This study will also explore whether there is any relationship between the oral sensation test and two tests of swallowing. This study will increase understanding of the relationship between oral sensation and swallowing and provide information on oral sensation in healthy adults that could be used in future with patients.

If you choose to take part in this study, your involvement in this project will require you to attend one session, approximately 60 minutes in length. During this, you will be seated comfortably in a chair and asked to complete 3 tasks. The first task is an assessment of oral sensation. You will be shown the shapes used in the task, 20 different shapes in 3 different sizes, 60 shapes in total. The researcher will ask you to close your eyes and then place a shape in your mouth using sterile tweezers. You will be instructed to use your mouth and tongue to identify the shape and point to the shape using a chart with pictures of all 20 shapes. This will be completed for all 60 shapes. You will be offered a break and sips of water during this task. Approximately 40 minutes is needed for this task. The researcher will then set up a video camera or iPad to record the next 2 tasks. This is to ensure accurate measurements are taken. The video will be set up to record only the lower portion of your face (from the nose down). You will be asked to drink a single cup of water as fast as is comfortably possible and eat a quarter of a salada cracker. Approximately 10 minutes is needed for these two tasks. Sterilisation procedures are in place for all materials used.

In the performance of the tasks and application of the procedures there are risks of swallowing or choking on the shapes, however, these risks will be minimised by attaching a piece of dental floss to each shape and securing the dental floss to your clothes with a peg.

Participation is voluntary and you have the right to withdraw at any stage without consequence. You may ask for your raw data to be returned to you or destroyed at any point. If you withdraw, I will remove all information relating to you. However, once analysis of raw data starts on 1st November 2019 it will become increasingly difficult to remove the influence of your data on the results.

In appreciation for your time, you will receive a $10 travel voucher. If you choose to withdraw at any stage, you will still receive the travel voucher.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public. To ensure confidentiality, you will be assigned a number and all data collected will be stored under this number in electronic password protected form. The consent forms will be the only document containing identifiable information and will be stored in a locked filing cabinet at the Rose Centre for Stroke Recovery and Research. You will be assigned a number and all data collected will be stored under that number in electronically password protected form. The researcher and her supervisors are the only people who will have access to the data. All data will be stored for 5 years and then destroyed by Professor Maggie-Lee Huckabee.

The collected data may be used, in aggregate form, in future studies that have received ethical approval. Such studies might include a comparative study using the same protocol, or a similar protocol, for patients that have swallowing difficulties.

A thesis is a public document and will be available through the UC Library. Please indicate to the researcher on the consent form if you would like to receive a copy of the summary of results of the project.

Georgia Holland is carrying out the project as part of the Master of Science in Speech and Language Sciences degree under the supervision of Professor Maggie-Lee Huckabee, who can be contacted at maggie-lee.huckabee@canterbury.ac.nz.

She will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and return to the researcher in person before participating in the study.

Appendix 2: Consent Form

Department: School of Psychology, Speech and Hearing co-hosted with the Rose Centre for Stroke Recovery and Research
Telephone: +64 3 369 2385
Email: georgia.holland@pg.canterbury.ac.nz

HEC Ref: HEC 2019/97

Consent Form for Participants

The relationship between oral sensation and swallowing

- ☐ I have been given a full explanation of this project and have had the opportunity to ask questions.
- ☐ I understand what is required of me if I agree to take part in the research.
- ☐ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
- ☐ I understand that any information or opinions I provide will be kept confidential to the researcher and her supervisors and that any published or reported results will not identify the participants. I understand that a thesis is a public document and will be available through the UC Library.
- ☐ I understand if I choose to withdraw at any stage, I will receive the $10 travel voucher.
- ☐ I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
- ☐ I understand the risks associated with taking part and how they will be managed.
- ☐ I understand that the collected data may be used, in aggregate form, in future studies that have received ethical approval.
- ☐ I understand that I can contact the researcher Georgia Holland (georgia.holland@pg.canterbury.ac.nz) or supervisor Maggie-Lee Huckabee (Maggie-lee.huckabee@canterbury.ac.nz) for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)
- ☐ I would like a summary of the results of the project.
- ☐ By signing below, I agree to participate in this research project.

Name:__________________________Signed:_____________________Date:____________

Email address *(for report of findings, if applicable)*:

____

Please return this form in person to the researcher Georgia Holland before participating in the study.

Appendix 3: Advertisement Flyer

Department: School of Psychology, Speech and Hearing co-hosted with the Rose Centre for Stroke Recovery and Research
Telephone: +64 3 369 2385
Email: georgia.holland@pg.canterbury.ac.nz

HEC Ref: HEC 2019/97

Looking for participants

Are you 55 years or older?

Exploring Oral Sensation and Swallowing

We are looking for volunteers with no swallowing difficulties to participate in a study that will increase our understanding of the relationship between oral sensation and swallowing.

If you consent, you will participate in 1 session, approximately 60 minutes in duration, at the Rose Centre for Stroke Recovery and Research. You will be asked to identify the shape of small plastic pieces placed in your mouth by pointing to a picture of the shape on a chart. You will then be asked to drink a glass of water and eat a cracker.

In appreciation for your time, you will receive a $10 travel voucher.

For more information or to participate in the study please contact Georgia Holland at georgia.holland@pg.canterbury.ac.nz or on

03 369 238

Appendix 4: Data Collection Sheet

THE UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
ROSE CENTRE
FOR STROKE RECOVERY & RESEARCH
Te Puna Whakaora Rehu Ohotata
AT ST. GEORGE'S MEDICAL CENTRE
Ki te Whare Hauora o St.George

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Department: School of Psychology, Speech and Hearing co-hosted with the Rose Centre for Stroke Recovery and Research
Telephone: +64 3 369 2385
Email: georgia.holland@pg.canterbury.ac.nz

HEC Ref: HEC 2019/97

Data Collection Sheet

Exploring Oral Sensation and Swallowing

Participant Number:

1. Date of birth: ___________________

2. Gender: ☐ Male ☐ Female ☐ Other

3. What ethnic group do you belong to?

☐ New Zealand European ☐ Fijian
☐ Māori ☐ Tongan
☐ Samoan ☐ Niuean
☐ Other ____________________

4. Do you suffer from the effects of any of the following medical problems?

☐ Stroke

☐ Swallowing Difficulties

☐ Dementia

☐ Any brain related condition or illness causing brain injury

☐ Pain or problems with your jaw, temporomandibular joint (TMJ), or chewing

- ☐ Head and/or neck injury/surgery
- ☐ Head and/or neck cancer
- ☐ Neurological Disorder (e.g. Parkinson's Disease)
- ☐ Muscular Disease (e.g. muscular atrophy)
- ☐ Significant visual impairments

If you ticked any of the above medical problems, please describe:

____

____

5. Do you have any other medical problems which you feel may impact your swallowing?

   Yes / No (Circle one)

   If yes, please describe:

   ____

   ____

6. Are you currently taking any medications that may affect your swallowing?

   Yes / No (Circle one)

   If yes, please describe:

   ____

   ____

7. Please circle the option that best describes your dentition:

   Own Teeth **Partial Dentures** **Full Dentures** **No Dentition** **Other**

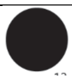
   If other, please describe:

   ____

   ____

8. Are you coeliac or following a gluten free diet?
Yes / No (Circle one)

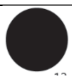
Small

Shape	**Time (seconds)**	**Score (0, 1, 2)**
		
		
		
		
		
		
		
		
 9		
 10		
		
		
		
		
		
		
		
		
		
		

Medium

Shape	Time (seconds)	Score (0, 1, 2)
		
		
		
		
		
		
		
		
 9		
 10		
		
		
		
		
		
		
		
		
		
		

Large

Shape	Time (seconds)	Score (0, 1, 2)
		
		
		
		
		
		
		
		
		
		
		
		
		
		
		
		
		
		
		
		

TWST

“I want you to drink this as fast as is comfortably possible”

Time	Swallowing Events

Volume per swallow:

Time per swallow:

Volume over time:

TOMASS

“I want you to eat this as quickly as is comfortable possible. When you have finished, say your name (or say hello)”

Time	Bites	Masticatory Cycles	Swallowing Events

Masticatory cycles per bite:

Swallows per bite:

Time per bite:

Time per masticatory cycle:

Time per swallow: